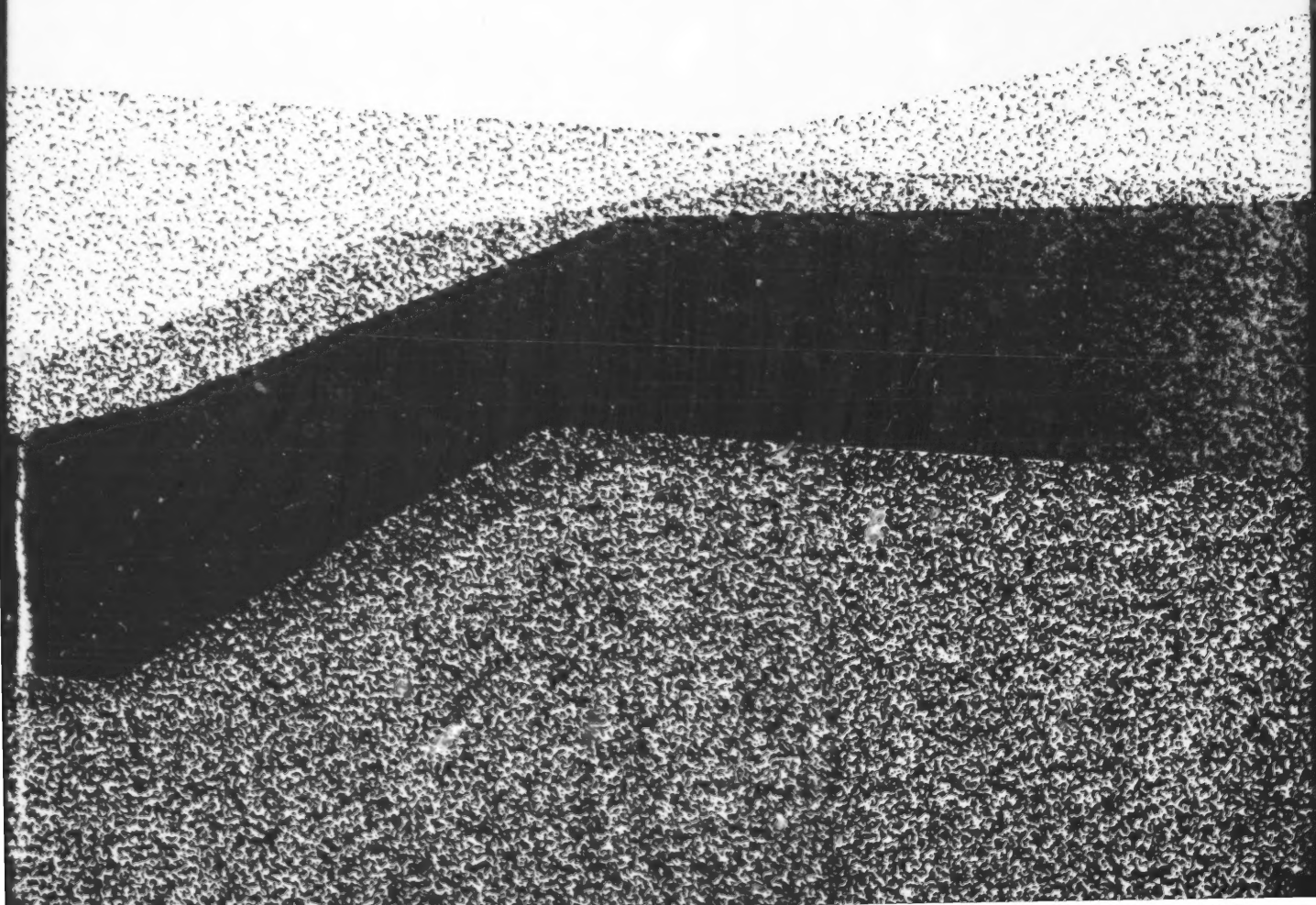
Centre for
Resource Studies

Queen's University
Kingston, Ontario

Effects of Public Policy on Investment Demand: The Case of Taxation in Canadian Base Metal Mining

BRIAN W. MACKENZIE
CHARLES H. PYE

Working Paper No. 26



EFFECTS OF PUBLIC POLICY ON INVESTMENT DEMAND: THE CASE OF TAXATION IN CANADIAN BASE METAL MINING

by

Brian W. Mackenzie

Charles H. Pye

CENTRE FOR RESOURCE STUDIES
Working Paper No. 26

December 1982

ISBN 088757/030/5
© Centre for Resource Studies, 1982
Queen's University

EDITOR'S FOREWORD

This paper represents research sponsored by the Centre for Resource Studies aimed at improving knowledge of the Canadian mineral industry and the political and economic environment in which it operates. In this study, the researchers examine the interest elasticity of Canadian mineral investment demand, and draw conclusions relating changes in taxation of the industry to changes in investment demand.

The Centre's working papers are offered for information and discussion, in an attempt to encourage feedback to the authors and additional research in mineral policy. Views presented are those of the author, and do not necessar'ly represent those of the Centre or its sponsors.

Margot J. Wojciechowski
Centre for Resource Studies

ACKNOWLEDGEMENTS

Michel Bilodeau provided valuable assistance with analysis of the empirical data.

Robin Boadway, Cydney McMurray, George Miller and David Yudelman read various drafts of the study and made helpful comments which are gratefully acknowledged.

CONTENTS

Editor's Foreword / iii

Acknowledgements / iv

Summary / vii

Résumé / viii

1 Introduction / 1

2 The Investment Decision: A Theoretical Framework / 2
The Discount Rate / 2
The Investment Decision: Alternative Criteria / 4
The Investment Demand Schedule / 6
Elasticity of Investment Demand / 11

3 Investment in Mineral Deposit Development / 14
Mineral Investment / 14
The Mineral Investment Decision Process / 15
The Effects of Public Policy / 17
Investment Demand / 17

4 Empirical Mineral Investment Demand Schedules / 19
The Data Base / 19
Investment Demand Curves / 21

5 Evaluating the Interest Elasticity of Investment Demand / 39

6 Conclusions / 51

The Authors / 53

Centre for Resource Studies / 54

CRS Publications / 55

TABLES

1. Metal Prices / 19
2. Base Case Conditions / 23
3. Mineral Endowment Variants / 26
4. Metal Price Variants / 26
5. Actual Mining Taxation System Variants / 30
6. Hypothetical Mining Taxation System Variants / 36
7. Taxation Systems: Constant Levels of Taxation / 37
8. Detailed Elasticity Estimates: Base Case Conditions / 42
9. Summary Elasticity Estimates: Base Case Conditions / 44
10. Elasticity Estimates: Mineral Endowment Variants / 44
11. Elasticity Estimates: Price Variants / 45
12. Elasticity Estimates: Actual Taxation Systems / 47
13. Elasticity Estimates: Hypothetical Revenue Taxation System / 47
14. Elasticity Estimates: Hypothetical Profit Taxation System / 48
15. Elasticity Estimates: Hypothetical Rate-of-Return Taxation System / 48
16. Elasticity Estimates: 1980 System Tax Level / 50
17. Elasticity Estimates: Three-Quarters 1980 System Tax Level / 50

ILLUSTRATIONS

1. Theoretical Investment Demand Curve / 7
2. Net Present Value, Rate of Return and the Investment Demand Curve / 10
3. Policy Effects on Investment and Elasticity of Investment Demand / 12
4. Investment Demand Curve: Base Case Conditions / 23
5. Investment Demand Curves: Mineral Endowment Variants / 25
6. Investment Demand Curves: Metal Price Variants / 27
7. Effect of Actual Mining Taxation Systems on Investment Demand / 29
8. Effect of Hypothetical Revenue Taxation System on Investment Demand / 32
9. Effect of Hypothetical Profit Taxation System on Investment Demand / 33
10. Effect of Hypothetical Rate-of-Return Taxation System on Investment Demand / 35
11. Empirical Investment Demand Curve for Base Case Conditions in Relation to Unitary Elasticity Investment Demand Curve / 40

SUMMARY

In a 1978 Ontario Ministry of Natural Resources (MNR) study, an evaluation of the effects of public policy on mineral investment is based critically on the assumption that the interest elasticity of mineral investment demand is unitary. This working paper examines this assumption empirically, using a data base constructed at the Centre for Resource Studies for 131 Canadian base metal deposits, and considering changes in federal and provincial taxation.

After a discussion of mineral investment behaviour, empirical investment demand schedules are constructed from this data base, showing the inverse relationship between the cumulative amount of mineral investment demanded and the minimum required rate of return on investment. Coefficients of the rate of return (or interest) elasticity of investment demand are estimated for a before-tax base case.

The base case results indicate that the interest elasticity of Canadian mineral investment demand is much less than minus one (unity) over the critical 5-to-15 percent range in the rate of return, where marginal mineral investment decisions are made. The estimated elasticity coefficients are:

Canada	-0.24
shield region	-0.15
cordilleran region	-0.28

The effect on interest elasticity of actual 1969, 1976 and 1980 Canadian tax systems, and hypothetical revenue, profit and rate-of-return taxation systems, is also evaluated, using the Canada-wide mineral investment data base. Although all the taxation regimes studied increase the elasticity coefficient, the increases are not as great as might be expected. The after-tax coefficients generally do not exceed -0.4 in the 5-to-15 percent rate-of-return range. Investment demand remains relatively inelastic after tax levies.

Since we find interest elasticity to be substantially lower than the MNR assumption of unity, the depressing impact of taxes on mineral investment can also be expected to be less than that predicted in the MNR study.

RÉSUMÉ

Dans une étude du ministère des Ressources naturelles de l'Ontario (MRN) faite en 1978, on a évalué les effets de la politique publique sur l'investissement minier en se basant sur l'hypothèse que l'élasticité d'intérêt de la demande d'investissements miniers était unitaire. Dans ce document de travail, on examine empiriquement cette hypothèse en se servant d'une base de données rassemblée au Centre for Resource Studies pour 131 gisement canadiens de métaux de base, et en tenant compte des modifications dans la fiscalité fédéral et provinciale.

Aprés avoir traité du comportement de l'investissement minier, on a établi, à partir de cette base de données, des tableaux empiriques de la demande d'investissements montrant le rapport inverse entre le montant cumulatif de l'investissement minier demandé et le taux minimal de rentabilité de l'investissement qui est necessaire. Les coefficients estimatifs de l'élasticité du taux de rentabilité (ou d'intérêt) de la demande d'investissement ont été établis pour un cas de base avant les prélèvements fiscaux.

Les résultats du cas de base indiquent que l'élasticité d'intérêt de la demande d'investissements miniers canadiens est bien inférieure à moins une (unité), pour un taux de rentabilité de 5 à 15 pour cent, quand des investissements miniers marginaux ont été faits. Les coefficients d'élasticité estimatifs sont de:

-0.24 pour le Canada
-0.15 pour la région du bouclier
-0.28 pour la région de la cordillère

On a évalué aussi l'effet sur l'élasticité d'intérêt des systèmes fiscaux canadiens réels de 1969 et 1980; et des régimes fiscaux hypothètiques basés sur le taux de rentabilité, le benefice et le revenue, en se servant de la base de données sur l'investissement minier dans tout le Canada. Bien que tous les régimes fiscaux augmentent le coefficient d'élasticité, les hausses ne sont pas aussi grandes qu l'on pourrait croire. Généralement, les coefficients aprés les prélèvements fiscaux ne dépassent pas - 0.4, pour un taux de rentabilité de 5 à 15 pour cent. La demande d'investissement reste relativement inélastique aprés la levée d'impôts.

Comme il est constaté que l'élasticité d'intérêt est considérablement moindre que dans l'hypothèse d'unité du MRN, on peut égalment s'attendre à ce que l'incidence négative des impôts sur l'investissment minier soit inférieure à celle prévue dans l'étude du MRN.

1. INTRODUCTION

It is generally believed that the changes in taxation of the mining industry and more stringent environmental regulations that were introduced in Canada in the 1970s have seriously eroded investment incentive. While any tax and any restrictive regulation would theoretically be expected to reduce investment activity, there has been little empirical evidence assembled on this subject. One study has attempted to quantify the impact of Canadian public policy on mineral investment demand. The Ontario Ministry of Natural Resources (MNR) produced a simulation study designed to show the proportional impact on investment in the mining industry of different taxation and environmental control packages on new and existing producers in Ontario, and in Canada at large. That study concludes that the combined effect of actual changes in taxation and environmental regulation was a reduction of at least 20 percent in the level of mineral investment that would have occurred in the absence of the policy changes.[1]

This is a striking finding, if it is accurate. However, the results depend critically on the assumption that the interest elasticity of investment demand is unitary.[2] The significance of this type of assumption is that the impact of public policy actions on the rate of return on investment can be translated directly into tax effects on the level of investment expenditure.

We examine the validity of the unitary elasticity assumption for base metal mining in Canada, using a Canadian base metal deposit-specific data base which has been developed at the Centre for Resource Studies. This data base is used to construct investment demand schedules to ascertain the magnitude of the interest elasticity of investment demand associated with the development of mineral deposits in Canada. Implications of policy changes for mineral investment demand are then evaluated. Our analysis is limited to the application of Canadian mining taxation systems to the investment schedules developed. Environmental regulations are not included here. Our findings are then compared with those of the MNR study.

---

1. G. Anders, W.P. Gramm, S.C. Maurice and C.W. Smithson, Investment Effects on the Mineral Industry of Tax and Environmental Policy Changes: A Simulation Model (Ontario Ministry of Natural Resources, July 1978). See especially pp. 2, 104.
2. Elasticity refers to the degree of responsiveness in a dependent variable to a change in an independent variable. In the present context, unitary interest elasticity of demand means that the percentage change in investment demand is equal to the percentage change in the rate of return. Since this assumed one-to-one relationship between investment demand and rate of return is inverse, the term 'unitary elasticity' refers to an elasticity of minus one.

2. THE INVESTMENT DECISION: A THEORETICAL FRAMEWORK

The MNR study of the responsiveness of investment demand to tax and environmental policy changes is grounded in the simple theory of the investment decision of the firm. In examining the MNR study, we begin with a discussion of this theoretical framework. Our discussion involves four main steps:

i since the investment decision is integrally linked with the discount rate, we briefly discuss this concept;
ii we set out the conventional alternative approaches to evaluating a single prospective investment project of the firm;
iii we proceed from the single-investment case to the multiple-project case and the procedures for ranking a menu of independent investment prospects, and for deriving an investment demand schedule;
iv we adapt the approach used in the MNR study to show theoretically that the study's assumption of unitary interest elasticity of investment demand is a special and very restricted case.

These steps are conducted as a purely theoretical exercise; that is, they are carried out without reference to empirical data. However, this discussion does include an a priori statement about the interest elasticity of investment demand based on knowledge of the characteristics of the Canadian mineral environment and on general properties of mining projects.

Chapters 3 to 5 involve the application of the theory to empirical assessments of investment demand schedules, the interest elasticity of investment demand, and the effects of taxation on mining investment opportunities.

The Discount Rate

The discount rate is the price of obtaining and applying funds to finance a capital project. For any investment opportunity, the discount rate applied will critically affect the economic justification of the project.

Under a certain set of assumptions, the discount rate is simply the market rate of interest. These assumptions, however, represent a perfect capital market:

i funds can be loaned or borrowed in any amount without affecting the lending or borrowing rate;
ii lending and borrowing interest rates are identical;

iii there is only one debt instrument in the economy, yielding only one interest rate;
iv there is no uncertainty.

The market rate of interest is both the price of using funds to finance a capital project, and the income forgone (opportunity cost) on lendable funds in the firm's possession by investing in its own project rather than lending out the money. At the same time, it is the rate at which cash flows can be invested as they are realized from the operation of the project.

The real-world situation is different, however:

i capital markets are not perfect;
ii lending and borrowing rates are not identical;
iii there is a wide range of debt and equity instruments and interest rates;
iv the future is uncertain.

Under such circumstances, it is a fiction to talk about the market rate of interest and the discount rate. For each prospective investment, the discount rate will depend upon both the nature of the project's financing and the economic environment against which the project's expected performance is evaluated.

The variability of the discount rate can be shown simply by relaxing the assumption that lending and borrowing rates are the same. Normally, an individual or a firm confronts a borrowing rate that is higher than the lending rate in financial markets. This spread means there is no single common value for the discount rate, but rather a range varying from the lending rate (income forgone on lendable funds in the firm's possession) to the borrowing rate (the price of obtaining funds to finance a project).

In determining the discount rate under conditions of uncertainty, it is also necessary to distinguish between debt and equity sources of funds used to finance new capital projects. The interest costs associated with acquiring debt or issuing equity instruments are different because of differences in the uncertainty and risk perceived by prospective investors. Owing to its prior claims on the assets of a project, debt usually carries a lower interest cost than equity. Conventionally, therefore, the composite discount rate for a prospective investment project is the weighted average of the explicit market cost of debt funds and the implicit opportunity cost of equity funds.

While there is no single approach to determining the discount rate in deciding whether to proceed with an investment opportunity, and how much money to com-

mit, the prospective return has to be evaluated against the discount rate. Some minimum acceptable rate of return has to be selected: ultimately, this rate has to be established on a case-by-case basis. The role of the discount rate in assessing the return on investment will be discussed below with regard to alternative investment decision criteria.

The Investment Decision: Alternative Criteria

Any single investment opportunity must be evaluated on a case-by-case basis. This involves evaluating the prospective return on investment and comparing it with a minimum acceptable rate which justifies the investment.

In evaluating an investment opportunity, three alternative approaches are conventionally used: net present value; present value ratio; and rate of return. All three criteria give equivalent results with respect to the actual level of investment justified, since they all prescribe only that total amount of investment in which the return from each and every project is equal to, or exceeds, the discount rate. The three differ, however, in their ranking of alternative investment opportunities. The criteria are outlined below.

Net Present Value (NPV)

A single prospective investment project has a capital cost, C, and the outlay is assumed to be made at the beginning of the project, at time 0. The capital good is expected to generate over its productive life of T years a series of annual cash flows,

$$R_1, R_2, \ldots, R_T.$$

This series of cash flows is discounted by the discount rate, i, to time 0 and the capital cost (C) is subtracted to yield the net present value, NPV, of the investment.[3] Thus,

$$NPV = -C + \frac{R_1}{(1+i)} + \frac{R_2}{(1+i)^2} + \ldots + \frac{R_T}{(1+i)^T}$$

3. We assume that the capital good has no scrap value at the end of its life.

In abbreviated notation, we have,

$$NPV = -C + \sum_{t=1}^{T} \frac{R_t}{(1+i)^t}$$

The decision to proceed with the project is governed by the following rules:

i if $NPV \geq 0$, proceed;
ii if $NPV < 0$, do not proceed.

Present Value Ratio (PVR)

The present value ratio (PVR) is simply the net present value per unit of investment, PVR = NPV/C. The decision rules are the same as for net present value; i.e.:

i if $PVR \geq 0$, proceed;
ii if $PVR < 0$, do not proceed.

Rate of Return (r)

An alternative procedure for evaluating an investment prospect is the rate of return. The rate of return is that discount rate which equates the discounted stream of all annual cash flows and capital outlays to zero. Continuing with the assumption that all investment occurs at time 0, the relationship is,

$$-C + \frac{R_1}{(1+r)} + \frac{R_2}{(1+r)^2} + \ldots + \frac{R_T}{(1+r)^T} = 0.$$

The investment decision is based on a comparison of the rate of return, r, with the discount rate, i. The decision rules are:

i if $r \geq i$, proceed;
ii if $r < i$, do not proceed.

Each of these approaches will determine the same equilibrium amount of investment, given the same discount rate. They do, however, have differing characteristics which affect the way in which they rank a number of alternative in-

vestment opportunities. This is significant for the purpose of this study, which involves the whole range of investment opportunities available to the mining industry.

A problem with the NPV criterion in ranking a number of opportunities is that the ranking is influenced by the relative scale of the projects. Since the NPV criterion ranks projects by the magnitude of their discounted cash flows, there will be a tendency for larger projects to be ranked ahead of smaller projects, even though relative profitability, as measured by the rate of return, may rank a smaller project as more attractive than a larger one. This shortcoming of the NPV criterion can be overcome by applying the present value ratio (PVR).

While the PVR overcomes the problem of differing scale of projects in influencing the ranking, there remains a further limitation of both the NPV and the PVR criteria for ranking investment opportunities. Both of these criteria depend critically upon the selection of an appropriate discount rate. It has already been pointed out that there is no universal way of determining the discount rate, since it depends upon the particular characteristics of each situation. Furthermore, each time the discount rate changes, the NPVs and PVRs have to be recalculated. An advantage of the rate of return criterion is that projects can be ranked independently of the discount rate.

The Investment Demand Schedule

The Firm

From the ranking of a number of alternative investment projects according to projected rates of return, an investment schedule or curve can be derived. In constructing the theoretical investment demand schedule, our starting point is the firm.

The theoretical investment demand curve of the firm developed in this section is based on the following set of assumptions:

i the firm has a given set of heterogeneous investment prospects, i.e. their profitability differs;
ii the projects are independent;
iii investment occurs continuously from project to project, i.e. there is no lumpiness in the investment stream (this yields a smooth curve);
iv all investment can be accomplished in the given time period, i.e. there are no lagged adjustment problems;
v all projects yielding a rate of return equal to or greater than the discount rate will be undertaken, i.e. there are no capital constraints.

The firm's investment demand schedule, or curve, is derived directly from the ranking of the available set of investment prospects according to their rates of return. Ranking the projects in descending order of profitability traces out a schedule of returns for the menu of investment projects. The resulting theoretical investment demand (ID) curve is depicted as figure 1. No significance should be attached to the fact that the curve shown in figure 1 is a straight line. The shape of the curve for each firm is determined empirically, and cannot be predicted theoretically, beyond the fact that the slope will be negative.

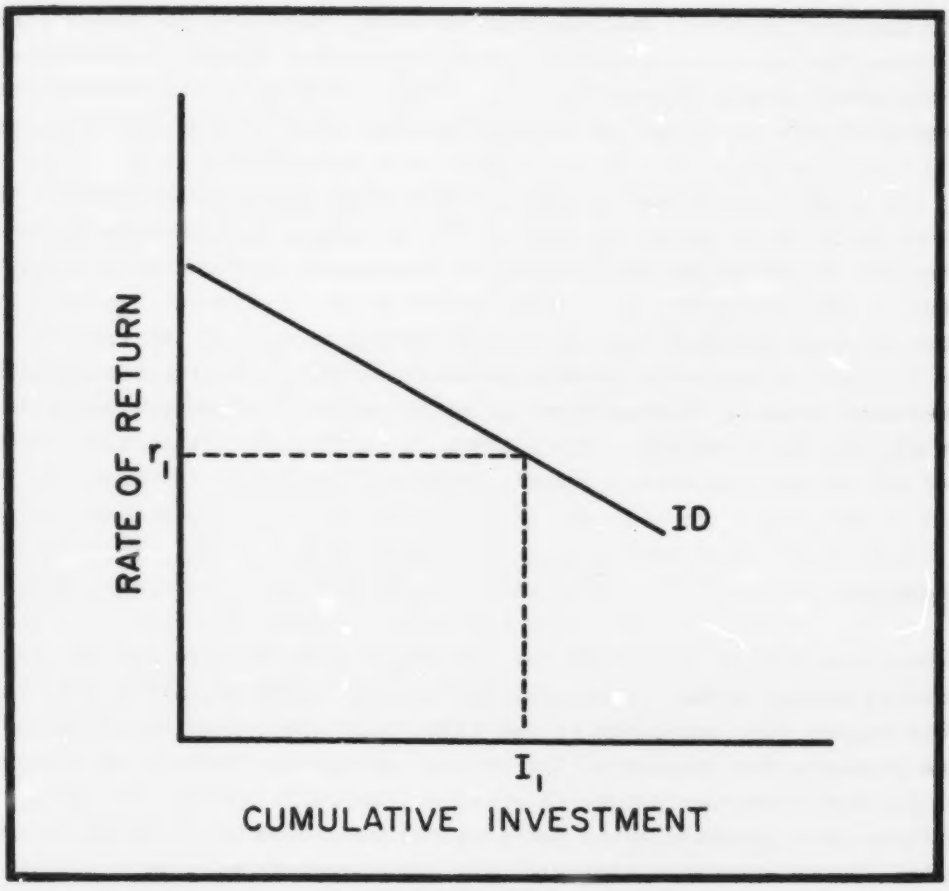


Figure 1. Theoretical Investment Demand Curve

A number of features of the demand curve should be noted. First, the demand curve shows that for any specified rate of return, r_1, associated with the marginal project there is a corresponding cumulative amount of investment demanded, I_1. Investment demand is, therefore, a schedule of cumulative (or total) investment expenditure that would be forthcoming at different marginal rates of return. This is the basic investment demand curve in the theory of investment behaviour, and is the marginal return on investment (MRI) curve used in the MNR study, referred to in our study as the investment demand (ID) curve.

Second, given the investment demand curve, the amount of investment that will be undertaken will depend on the discount rate, or minimum acceptable rate of return, assigned by the firm. If, for instance, the discount rate is identical to r_1, then the amount of investment expenditure the firm will undertake is I_1, since all projects encompassed by this cumulative level of investment satisfy the test that rate of return be greater than or equal to the discount rate.

Third, the elasticity of the investment demand schedule is interpreted with reference to movement along the curve. The elasticity of investment demand measures the degree of responsiveness of investment to the change in the rate of return. Elasticity is the percentage change in investment demanded in response to a one-percent (not percentage point) change in the rate of return.[4] This coefficient, closely defined, is the rate-of-return elasticity of investment demand. Conventionally, it is referred to as the interest elasticity of investment demand. Since there is an inverse relationship between rate of return and investment demand, interest elasticity is negative.

The Industry

It is now necessary to transform the investment demand curve for the firm into an industry demand curve. Conceptually this is a simple procedure which involves aggregating horizontally the individual investment demand schedules of all the firms in the industry. The process of aggregation may involve additional factors which may not be relevant to the individual firm. Of particular significance are possible price and cost changes which will affect the shape and hence the interest elasticity of the demand schedule.

---

4. Constant elasticity means that the relationship between the one-percent change in rate of return and the corresponding change in investment demand is constant along the entire range of the curve. Unitary elasticity, as assumed in the MNR study, means that there is a constant one-to-one relationship between rate of return and investment demand throughout the schedule.

This brings us then to the final point in our theoretical discussion of the investment demand schedule - the shape of the industry schedule. The actual shape and elasticity of investment demand schedules for the Canadian base metal sector will be discussed and empirically derived in chapters 4 and 5 of this paper.

Net Present Value, Rate of Return, and Investment Demand

The theoretical background chapters in the MNR study describe investment demand as a schedule derived from the ranking of investment opportunities according to the rate-of-return criterion. The estimating model, however, appears to be based on the net present value approach to the investment decision process. The theoretical basis for this transition is not spelled out. Consequently, it is desirable to consider here how both approaches relate to the derivation and shape of the investment demand curve. We will show that net present value cannot be used directly to generate an investment demand curve.

It was pointed out above that, given a specific discount rate, the rate of return, net present value, and present value ratio approaches will yield identical results for the cumulative investment expenditure that will be undertaken. The difference among these criteria is in the project ranking. The different approaches can thus be expected to produce different shapes of investment schedules.[5]

The relationships between net present value and rate of return, and NPV and investment, are illustrated in figure 2. The diagram shows that, while the investment schedules using the two criteria differ, both determine the same cumulative amount of investment given the same discount rate.

Panel A of the diagram shows a number of net present value schedules for the same set of investment opportunities at various discount rates, $i_0 < i_1 < i_2$. The higher the discount rate, the closer the net present value schedule is to the origin. The points of intersection on the investment axis demarcate those cumulative amounts of investment representing projects which have a net present value equal to or greater than 0. All points above the intersection are econo-

5. Note that the term investment schedule rather than investment demand schedule is used. This is deliberate. A schedule relating incremental project NPV to the cumulative total investment can be constructed, but the schedule is not an investment demand curve. This contrasts with the relationship between the marginal rate of return and the cumulative amount of investment, which portrays an investment demand curve.

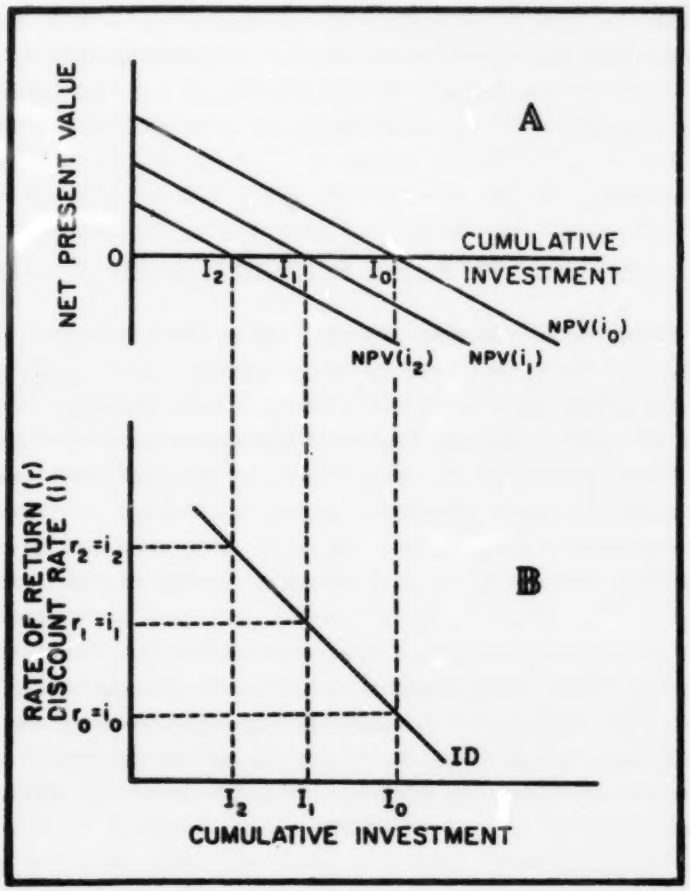


Figure 2. Net Present Value, Rate of Return and the Investment Demand Curve

mic, since net present value is greater than 0. All projects yielding an net present value of less than 0 are, of course, uneconomic. Thus, as the discount rate rises, the cumulative amount of investment declines, and the net present value schedule is displaced downward and to the left.

Panel B of the diagram is an investment demand curve showing the total amount of investment that would be undertaken at different marginal rates of return. The equilibrium amount of investment is established where the marginal rate of return is equal to the discount rate. This amount of investment is identical to that shown in panel A delineated by the net present value schedule for the same discount rate.

The relationship of panel A to panel B shows that, for any given discount rate, the net present value and rate-of-return criteria yield the same equilibrium level of investment. The two methods nevertheless have different implications for our purposes. For a given discount rate, the net present value criterion gives a different ranking of heterogeneous projects than does the rate of return. The rate of return ranks projects on the basis of their profitability only. Project ranking by net present value is governed by both profitability and project scale.

This difference can be illustrated with reference to the disparate nature of base metal deposits found in Canada. Small projects may have a high rate of return but because of their scale have a low net present value, approaching zero. Large-scale projects may have a rate of return in the neighbourhood of the discount rate, again yielding a net present value approaching zero. This will tend to spread investment along the investment axis for the net present value schedule around NPV = 0, compared to the investment demand curve at rates of return near the discount rate. In other words, the net present value schedule is flatter (and more 'elastic') than the investment demand curve in the neighbourhood of the discount rate.

Furthermore, the relationship of net present value to cumulative investment is somewhat cumbersome because its evaluation entails a different set of calculations for each possible value of the discount rate (as shown in figure 2). The investment demand curve is conceptually simple and can be derived empirically without reference to the discount rate. Thus, the remainder of this theoretical exposition and our empirical work uses the rate-of-return investment demand curve.

Elasticity of Investment Demand

The elasticity of the investment demand curve affects the impact of policy changes on investment. The higher the elasticity of the demand curve, the greater the policy impact will be. Figure 3 illustrates this proposition by comparing relatively elastic and inelastic investment demand curves, designated ID_e and ID_n respectively.

The initial situation is shown at the rate of investment I_1, with the discount rate i_1. The policy change shifts both the ID_e and ID_n curves down and to the left from ID_{e1} and ID_{n1}, to ID_{e2} and ID_{n2} respectively. At the original amount of investment, the policy effect is assumed to depress the marginal rate of return to r. However, since by assumption the discount rate is constant at i_1, the economic rate of return cannot fall below r_1. Therefore, the policy effect

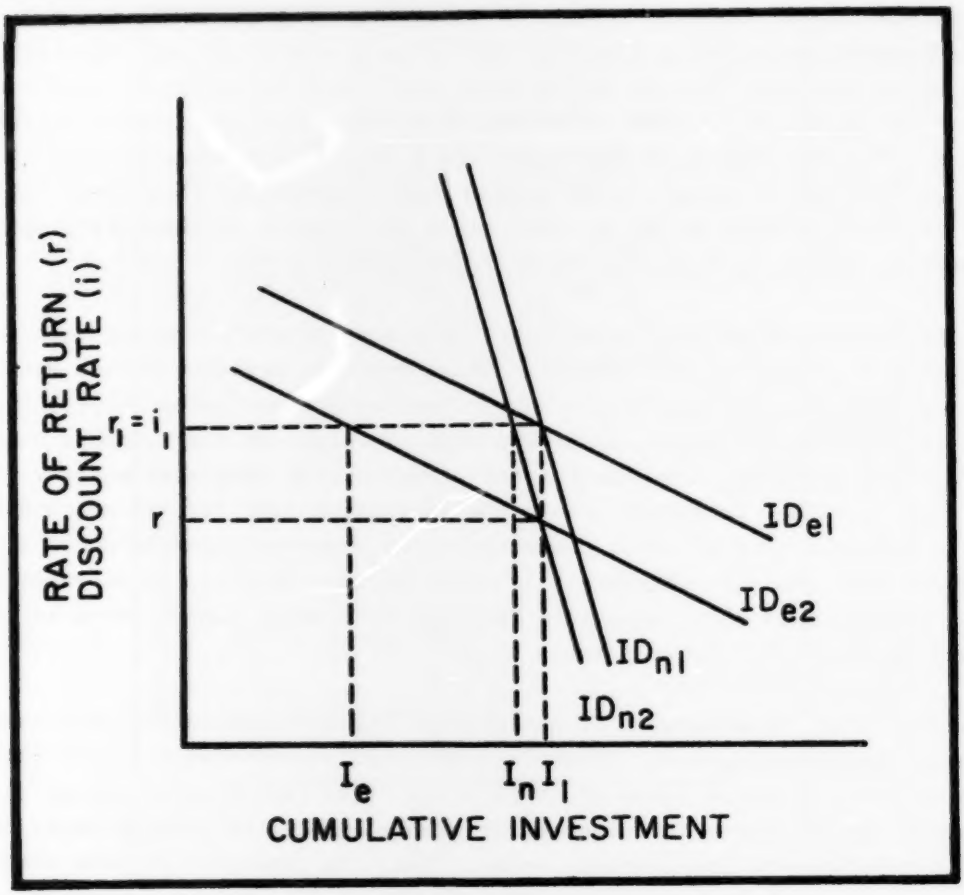


Figure 3. Policy Effects on Investment and Elasticity of Investment Demand

will be to reduce the level of investment. By construction, ID_e and ID_n shift down by the same amount. Since, however, ID_e is more elastic than ID_n, the policy impact on investment will be greater for the more highly elastic demand curve; that is,

$$(I_1 - I_e) > (I_1 - I_n)$$

Furthermore, the elasticity of the investment demand curve is affected by the form of the policy implemented. Chapters 4 and 5 show these effects based on empirical analysis.

One last point regarding elasticity of investment demand should be mentioned. The MNR study assumes that the investment demand schedule has unitary elasticity with respect to the rate of return. We propose to examine the MNR unitary elasticity assumption by using a set of Canadian deposit-specific data for base metal mining. This data base has two distinct advantages over the data used in the MNR study. First, the data are founded on actual mining investment projects. Second, the data deal with deposits in Canada.[6] Thus we have a body of data to which Canadian taxation policies are intimately related, and the direct impact of Canadian policies on Canadian mining investment prospects can be analyzed.

6. The empirical data applied in the MNR study is drawn from corporate income tax return statistics for total mining and for oil and gas extraction in the United States during the 1949-71 period. See G. Anders, S.C. Maurice, and C.W. Smithson (July 1978), appendix A, pp. 107-111.

3. INVESTMENT IN MINERAL DEPOSIT DEVELOPMENT

This chapter describes the evaluation process followed in actual mineral investment decisions. The purpose is to show that this process is consistent with the theoretical concepts outlined in chapter 2, before proceeding to our empirical assessment of the effects of public policy on mineral investment demand in chapters 4 and 5.

Mineral Investment

Investment decisions are made at a number of sequential points through the exploration, development, and production phases of mineral supply. The most significant decisions are made at the start of the mineral supply process, when exploration environments are selected for investment. Other exploration decisions must subsequently be made concerning the selection of areas, the screening of anomalies, the definition of drilling targets, and the amount of delineation justified for favourable discoveries. Over time, these exploration activities yield possible economic discoveries for evaluation.

Each possible economic discovery is evaluated to determine, first of all, the best set of specifications for a new mine development project. The variables considered at this stage may include a range of mine capacities, methods of sequencing mining, degrees of capacity utilization, levels of cut-off grade, and stockpiling tactics. The economic justification of investment in mine development is then considered, based on this best set of specifications.

The construction and production activities which follow a decision to develop a mine embody a range of operational investment decisions including equipment selection and replacement, development of ore reserves, modification of mining methods and mineral processing facilities, and the expansion of mine capacity.

The focus of this paper is on major investment in new mine developments and the operational investments related to such development. These activities have been estimated to account for approximately 80 percent of the total investment which is made from the start of exploration to the production of concentrate in the Canadian base metal sector.[7]

---

7. B.W. Mackenzie and M.L. Bilodeau, Effects of Taxation on Base Metal Mining In Canada (Kingston: Centre for Resource Studies, 1979), p. 32.

The Mineral Investment Decision Process

The starting point for any mineral investment decision is the information which is available concerning all relevant aspects of the deposit and its potential development. This includes such things as deposit characteristics, environmental parameters[8] and the skill and experience of personnel associated with the project. This information is used to estimate the benefits and costs which may result from the proposed investment. These perceptions are combined to derive possible time distributions of cash flows associated with the investment. There are three aspects to this estimation process. First, single-point estimates are made, based on conditions which are perceived to be 'expected' or 'most-likely'. Second, uncertainties have to be considered. Uncertainties arise because deposit characteristics can be examined only partially at the time of the decision and because the environmental parameters will only become fully known with time. Uncertainty estimates for the key project variables may be expressed as probability distributions of possible values about the 'expected' or 'most-likely' single-point estimates. Third, non-quantifiable intangible factors must also be considered in the decision process.

The possible time distributions of cash flows associated with a proposed mineral project form the basis of its economic justification. These estimates neglect one important cost element, however: the cost associated with the funds required for investment as expressed in the discount rate. Clearly, the return on investment, as determined by the possible time distributions of cash flows, must exceed the discount rate if investment is to be justified.

Time value is used to express and compare the discount rate and the return on investment. Discounted cash-flow methods combine the concepts of cash flow and time value for the economic evaluation of investment in a mineral deposit development. Three discounted cash-flow methods are used to assess the economic viability of the project: net present value, present value ratio, and rate of return. Their characteristics and applications as criteria for reaching investment decisions were discussed in chapter 2.

When these discounted cash-flow methods are applied to the single-point expected value estimates associated with a mineral investment opportunity, expected profitability decision criteria are derived. When the methods are applied to the uncertainty estimates for the key project variables, probability distributions of profitability outcomes about the expected values may be assessed using

8. Environmental parameters refer to the broad spectrum of factors external to the deposit itself and existing (or expected to exist) in the area and during the period in which the deposit is to be developed and mined, e.g. market prices, operating and capital costs, public policy conditions.

an appropriate risk-analysis technique. While investment risk is represented by this overall distribution, risk-averse investors will be particularly concerned with the lower part of the distribution. Thus following two risk criteria are of particular interest.

i Insurable lower-limit value: this value is determined so that there is a reasonable degree of confidence of achieving a discounted cash-flow result of equal or greater value; e.g. the 90 percent lower-limit rate of return.
ii Probability of economic loss: the probability that the discounted cash-flow outcome will fall below the minimum acceptable value required to justify investment; e.g. the probability that the rate of return for an investment will in fact be less than the discount rate.

Thus, the mineral investment decision is taken in the light of three basic considerations:

i expected profitability criteria based on the three discounted cash-flow indicators;
ii risk criteria, as outlined above, for each of the discounted cash-flow indicators; plus
iii non-quantifiable intangible considerations which can only be taken into account in terms of qualitative judgment.

Assuming the same relative dispersion of the probability distribution of expected profitability, an investment indicating a higher expected profitability will be preferred to one with a lower expectation. Similarly, to the extent that investors are risk averse, an opportunity with lower risk will be preferred. Management subjectively assigns a relative weighting among the expected value, risk, and intangible considerations based on its preferences. This enables the ranking of investment opportunities in order of attractiveness down to a cutoff point below which opportunities are considered uneconomic. This cutoff also fixes the cumulative or total amount of investment which will be demanded.

The cutoff point is critical. It is based on the characteristics of the opportunity at the margin of investment in relation to the discount rate. The discount rate that is applied is a weighted average of the explicit borrowing cost of debt funding and the implicit opportunity cost of equity funding. At the cutoff point there should be a 'reasonable' chance that the actual return on investment will exceed this discount rate.

In practice, the mineral investment decision process may not be as explicit and formalized as the procedures discussed above. In any case, it is a useful

conceptual representation of the decision process adopted by rational investors.

The Effects of Public Policy

Public policies affecting mineral development are a fundamental consideration in the investment decision process just outlined. Policies may have either positive or negative effects on mineral investment decisions. For example, government support for the provision of infrastructure associated with a remote mineral development improves the decision criteria by relieving the investor of part of the project's overall capital requirement. On the other hand, compliance with environmental control policies increases the capital and operating costs for mining projects, thereby reducing investment incentive.

The focus of this study is on the effects of mining taxation policies on mineral investment decisions. The effects of taxation changes may similarly be positive or negative. A positive policy change could include write-off provisions for the determination of taxable income which reduce the burden of taxation and increase after-tax cash flows and the incentive to invest. However, the overall effect of taxation is usually to reduce after-tax cash flows, resulting in a deterioration of investment criteria.[9]

The main effect of a public policy action on investment criteria is to shift the entire probability distribution of possible profitability outcomes up or down, depending on whether the effect is positive or negative. Thus both the expected profitability and the risk criteria will be either enhanced or eroded. However, the relative magnitude of the changes in expected value and risk will not likely be the same. The shape of the outcome distribution may also be altered. Furthermore, the overall effect of public policy on investment demand also depends on the relative weighting assigned by management to expected profitability, risk, and intangible considerations respectively.

Investment Demand

The mineral investment decision process is complex and evaluation practices are far from standardized. For decision-making purposes, each investment opportunity and investor have special characteristics which must be considered in judging the desirability of investment. These characteristics make it diffi-

9. While the overall effect of taxation is usually negative, exceptions are found in decisions which result in increased costs, and for marginal development opportunities where the present value of tax credits may exceed the present value of tax payments, thereby improving profitability.

cult to generalize about the cumulative investment in the mining industry and how it would be altered by various types of public policy.

Our study evaluates the relationship between the expected rate of return, derived from expected cash flow indicators, and cumulative investment. This evaluation is based on a set of actual deposit data for the Canadian base metal sector which represents current mineral endowment characteristics. We are especially interested in the relationship between the volume of investment and rate of return, and how it is affected by endowment characteristics and various types of taxation systems. We also propose to assess investment demand by imposing a cutoff on this relationship. For this purpose, it is assumed that positive investment decisions will be taken as long as the expected return on investment at least equals the discount rate. This provides a basis for evaluating how changes in public policy (mining taxation changes in particular) affect overall investment demand, an important and often-neglected aspect of mineral policy analysis.

Our empirical approach omits some aspects of the evaluation of mineral deposit development opportunities discussed earlier in this section. However, we feel that it is consistent with actual investment practice and is sufficiently realistic for the purpose of public policy analysis. The analysis does not consider project risk except to note that, in terms of policy effects, project risk will change more or less in phase with variations in expected profitability.[10] We are also ignoring the particular characteristics of individual investors within the industry, whose various strengths and weaknesses, financial structures, and investment preferences give rise to variations in investment behaviour. These simplifications are necessary to facilitate the analysis, but do not invalidate the findings.

10. The risk of overall industry and corporate investment environments is included in the discount rate used in the evaluation.

4. EMPIRICAL MINERAL INVESTMENT DEMAND SCHEDULES

The Data Base [11]

The data base for our examination of investment demand consists of cash-flow estimates for 131 base metal deposits discovered in Canada during the 1951-74 period. Assessments of cash-flow characteristics are made for all deposits in Canada taken together, as well as for the shield and cordilleran regions.

The base metal sector is defined to include copper, zinc, lead, and molybdenum deposits, together with any associated gold and silver content. Our evaluation includes all significant discoveries made in this sector during the 1951-74 period.

Each deposit is evaluated at the mine development decision point, on the basis of current economic and technological outlook conditions. Thus, assessments are made of the cash flow characteristics of the development and production phases of mining activity. All money values are expressed in constant 1979 dollars.

General market estimates are applied to evaluate the time distribution of revenues for each of the deposits. Metal price is both the most important and the most uncertain variable in the assessment of cash flows. Cash flows are therefore evaluated as a function of price. An expected or mean price outlook is bounded by upper- and lower-limit prices for each mineral commodity. The prices used are shown in table 1.

TABLE 1
METAL PRICES
(1979 Dollars)

Commodity	Lower Limit	Expected Value	Upper Limit
Copper ($/lb.)	0.70	1.05	1.50
Zinc ($/lb.)	0.40	0.50	0.70
Lead ($/lb.)	0.32	0.42	0.62
Molybdenum ($/lb. in concentrate)	4.50	7.00	10.00
Silver ($/oz.)	6.00	8.00	12.00
Gold ($/oz.)	200.00	270.00	450.00

11. Further details may be found in B.W. Mackenzie and M.L. Bilodeau, Effects of Taxation on Base Metal Mining in Canada.

The assessment of costs and revenues assumes that a base metal concentrate is produced at each possible mine. General net smelter return conditions for copper, zinc, and lead concentrates, based on current outlook conditions, are used to work metal prices back to a revenue estimate for the sale of concentrate at the mine.

Individual deposit estimates of recoverable ore reserves, mill recovery, mine and mill capacity, capital costs, development period, and operating costs are made for each of the 131 base metal deposits, based on present-day economic and technological conditions.

Capital costs are subdivided into the following categories for estimating purposes:

i development capital costs - costs incurred during the development period for mine access, mine plant and machinery, mill facilities, infrastructure, and working capital;
ii sustaining capital costs - routine costs incurred in the production period for the replacement of plant and equipment;
iii other capital costs - costs incurred for major modifications during the mine's productive life, such as for the conversion from open pit to underground operations or the development of a new ore zone.

Operating costs are subdivided into mining, milling, and overhead components for estimating purposes.

The individual deposit estimates are based primarily on actual data obtained from published sources and directly from mining companies. The data are used to estimate the development and production characteristics for each deposit, assuming that it would be developed today under conditions reflecting the current economic and technological climate. Actual data for individual deposits were obtained for about 90 percent of the data elements. In the few cases where data were not available, estimates are based on generalized relationships reflecting typical experience in the environment concerned.

The general market and individual deposit estimates are applied to evaluate the time distribution of cash flows for each potential mine. Results are expressed in terms of the standard discounted cash-flow criteria: net present value, present value ratio, and rate of return. Assessments are made on each of the following two bases.

i On a potential value basis, including all direct costs and revenues. This assessment represents what is potentially available before taxes, and reflects the fundamental value of mineral endowment.

ii On an after-tax basis, considering the application of appropriate actual and hypothetical mining taxation systems to the overall potential values.

The term 'investment', as used in our study, refers to the total of development capital costs, sustaining capital costs, and other capital costs for each deposit as defined above. We are interested in the relationship between demand for investment and profitability, as reflected by the rate of return criterion.

Investment Demand Curves

In chapter 2 a theoretical investment demand curve was developed, where investment demand is a function of the rate of return. Now we proceed to derive empirical mineral investment demand curves from the data base of 131 base metal deposits discovered in Canada during the period 1951-74. It is desirable first, however, to relate the theoretical framework to an actual mineral investment demand schedule, to provide a bridge between the theoretical and the empirical.

The theoretical investment demand curve is based on the assumptions that:

i the firm has a set of independent and heterogeneous investment prospects;
ii investment occurs continuously; and
iii all investment intentions are executed in the time period being considered.

These assumptions make it possible to rank all investment opportunities in descending order of profitability, and to produce a smooth negatively sloped investment demand curve for the firm that incorporates the full range of investment intentions at various marginal rates of return. The industry demand curve is obtained by summation of the demand curves of the individual firms.

How do the conditions underlying the theory relate to the mineral deposit data base from which we propose to develop empirical demand curves? Let us consider the assumptions one at a time.

i The mineral deposits are spatially separated. All mineral investment opportunities can therefore be regarded as independent of one another and can be ranked in order of profitability. Mineral deposits are by nature heterogeneous. Base metal orebodies differ in characteristics such as deposit size, ore grade, and the mixture of metals contained. Deposit heterogeneity will yield a negatively-sloped investment demand schedule.

ii Mine development projects are lumpy investment undertakings. This lumpiness imparts a step-like shape to an investment demand curve but does not affect the essential property of an investment schedule, namely the inverse relationship between the quantity of investment demanded and the rate of return.

iii It usually takes a number of years to complete a mine development project from the time the decision is made to proceed. In terms of the actual time pattern of capital expenditure, these lags would have to be taken into account. For our purposes, however, we are interested in investment demand in the ex ante or planning sense of how much decision makers would be willing to invest at various rates of return.

The empirical conditions diverge, though not critically, from the theoretical construct in the procedure used to create an industry or sector demand curve. The theoretical demand curve is based on the behaviour of individual firms, with the industry curve obtained by aggregating the demands of firms in the industry. Using the data base of 131 base metal deposits, it is not possible to derive investment demand curves for individual firms owning the deposits. We are forced, therefore, to short-circuit this part of the theoretical process and to build up a base metal sector investment demand curve in one operation. This means proceeding as if all investment were to be undertaken by one base metal mining firm which can rank its menu of 131 investment prospects according to rate of return. Thus, the empirical investment demand curves used in this study show the ranking of mineral deposits in decreasing order of profitability as measured by the rate of return criterion.

The base case conditions to which other results are compared consist of potential value or before-tax assessments for all 131 base metal discoveries made in Canada during the period 1951-74, assuming expected metal price conditions. These conditions represent the empirical standard against which we evaluate mineral endowment and metal price variants, and the effects of mining taxation policies on investment behaviour.

The base case investment demand schedule is produced as figure 4. This diagram shows the cumulative total of investment demanded at various rates of return. Based on these results, table 2 illustrates the sensitivity of the number of deposits justifying development and, thus, cumulative investment demand to changes in the discount rate within the range of 5 percent to 15 percent. As the discount rate is increased through this range, the number of economic deposits is reduced by about one quarter and cumulative investment demand declines by approximately one third.

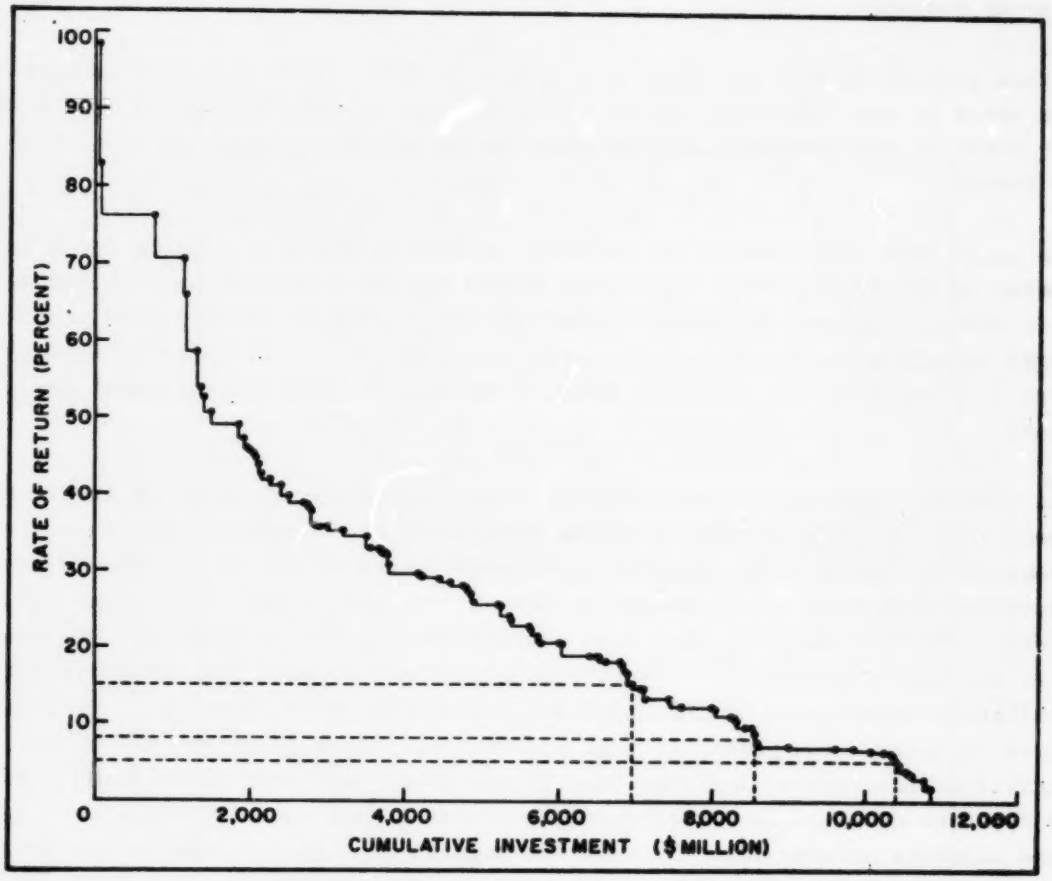


Figure 4. Investment Demand Curve: Base Case Conditions

TABLE 2
BASE CASE CONDITIONS

Discount Rate (Percent)	Deposits Justifying Development		Cumulative Investment Demand	
	Number	Percentage Change	Amount ($ million)	Percentage Change
5	97		10,400	
8	87	-24.7	8,560	-33.1
15	73		6,960	

Mineral Endowment

Before proceeding with the empirical analysis, some comments should be made on the shape of the investment demand curve yielded by the 131-deposit data base. The shape is fundamentally attributable to the nature of Canadian base metal endowment.

The upper left-hand segment of the curve generally reflects results for a large number of relatively small high-grade deposits, characterized by high and variable rates of return and modest investment requirements. Moving down, the curve incorporates the relatively large low-grade deposits, characterized by more marginal and less variable rates of return and heavier investment demands.

The apparent dichotomy between deposit types raises the question of investment demand varying with the nature of the geological environment. This issue is examined in figure 5 by comparing investment demand schedules for the two most important base metal environments in Canada, the shield and cordilleran regions, otherwise assuming base case conditions. It can be seen that the massive sulphide deposits which typify the shield environment have characteristics similar to those shown by the upper left-hand segment of figure 4, i.e. a steep curve resulting from generally high and variable rates of return and modest individual investment requirements. On the other hand, the cordilleran region is typified by large low-grade porphyry deposits, and thus its investment demand schedule is more like the downside segment of figure 4, i.e. a flatter curve resulting from generally more marginal and less variable rates of return and heavier investment demands. Table 3 summarizes the sensitivity of the number of deposits justifying development within the shield and cordilleran regions and, thus, of cumulative investment demand to changes in the discount rate within the 5 to 15 percent range.

In the cordilleran region, the number of economic deposits and cumulative investment are obviously much more sensitive to changes in the discount rate than in the case of shield region endowment. The deposits rendered uneconomic in the cordilleran region are larger than average (in terms of investment requirements) whereas those which drop out in the shield region are smaller than average. Differences in regional endowment characteristics, as reflected by the sensitivities shown in table 3, have important implications for policy analysis.

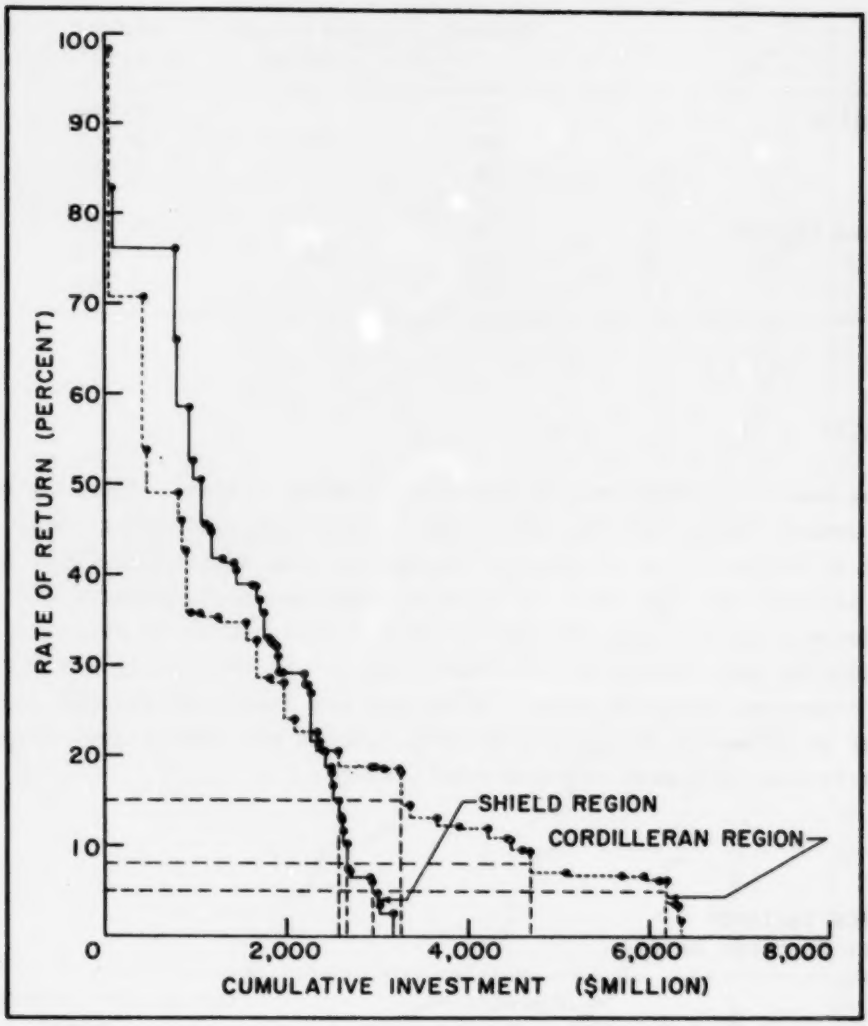


Figure 5. Investment Demand Curves: Mineral Endowment Variants

TABLE 3
MINERAL ENDOWMENT VARIANTS

	Discount Rate (Percent)	Deposits Justifying Development		Cumulative Investment Demand	
		Number	Percentage Change	Amount ($ million)	Percentage Change
Shield region	5	44		2 950	
	8	40	-18.2	2 660	-13.2
	15	36		2 560	
Cordilleran region	5	34		6 190	
	8	29	-38.2	4 680	-47.3
	15	21		3 260	

Metal Prices

Investment demand is obviously a function of metal prices. Figure 6 shows investment demand curves for the lower limit, expected, and upper limit prices specified in table 1. As prices are increased, the profitability of mining projects is enhanced, and thus the demand schedules shift upwards and to the right. Table 4 illustrates the sensitivity of the number of deposits justifying development and cumulative investment demand to changes in metal prices given an 8-percent discount rate. As prices are increased through this range, the number of economic deposits more than doubles and cumulative investment demand increases by almost one-and-a-half times.

TABLE 4
METAL PRICE VARIANTS
(8-Percent Discount Rate)

Metal Prices	Deposits Justifying Development		Cumulative Investment Demand	
	Number	Percentage Change	Amount ($ million)	Percentage Change
Lower limit	48		5 060	
Expected value	87	+116.7	8 560	+145.5
Upper limit	104		12 420	

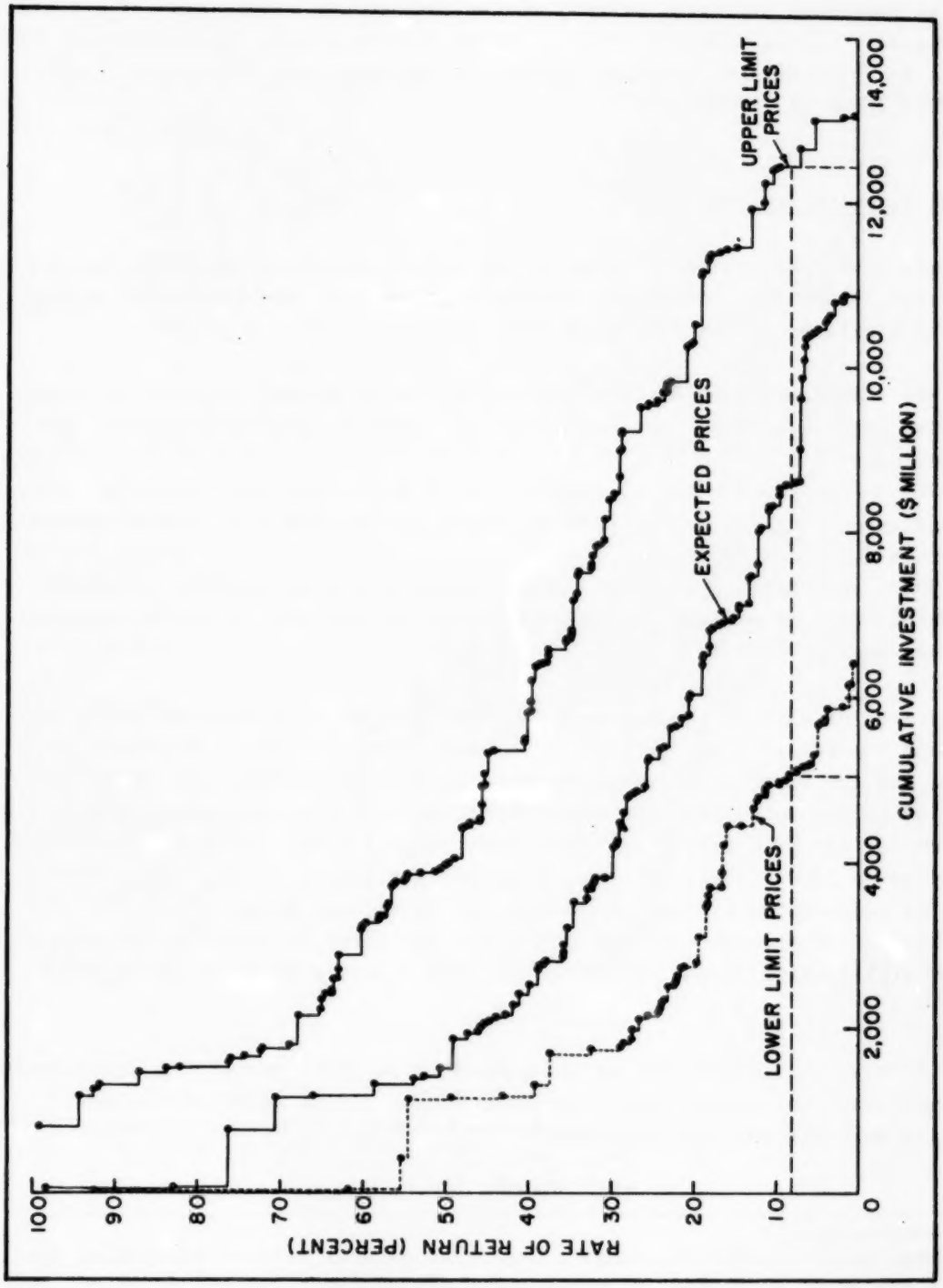


Figure 6. Investment Demand Curves: Metal Price Variants

Bearing in mind that the characteristics of investment demand are a function of mineral endowment and metal prices, we now turn to the examination of a third determinant, mining taxation policy. We do this by evaluating the effects of actual and hypothetical taxation systems on the base case investment demand schedule shown in figure 4.

Actual Taxation Systems

Initially, we consider the effects of the actual systems of Canadian federal corporate income tax, provincial corporate income tax, and provincial mining tax which existed at the following three points in time.

i 1969 - representing the 'traditional' system of mining taxation in Canada with generous federal tax incentives and passive, modest provincial tax policies.

ii 1976 - representing mining taxation as it would have been following federal tax reform and the substantial increases in tax burden in some provinces which followed that reform.

iii 1980 - representing the most recent system of mining taxation in Canada which could be analyzed, taking post-1976 federal and provincial changes into account.

The effects of each of these actual taxation systems on investment demand are shown in figure 7.[12] As taxation is imposed, after-tax rates of return decline, and the investment demand schedule is shifted downward and to the left relative to the potential base case conditions. This displacement is most pronounced for the 1976 system and least pronounced for the tax conditions which prevailed in 1969. There has been a significant easing in tax burden since 1976, as illustrated by the position of the investment demand curve for 1980 conditions. It appears that the 1980 curve is closer to the 1976 schedule at higher profitabilities and closer to the 1969 schedule at lower profitabilities.

Table 5 shows the sensitivity of the number of deposits justifying development and cumulative investment demand to these actual mining taxation systems assuming an 8-percent discount rate.

---

12. These taxation effects assume a 5-percent general rate of inflation, the expensing of 75 percent of exploration expenditures for tax purposes, and the taxation of development and production phases of investment on an individual project (stand alone) basis.

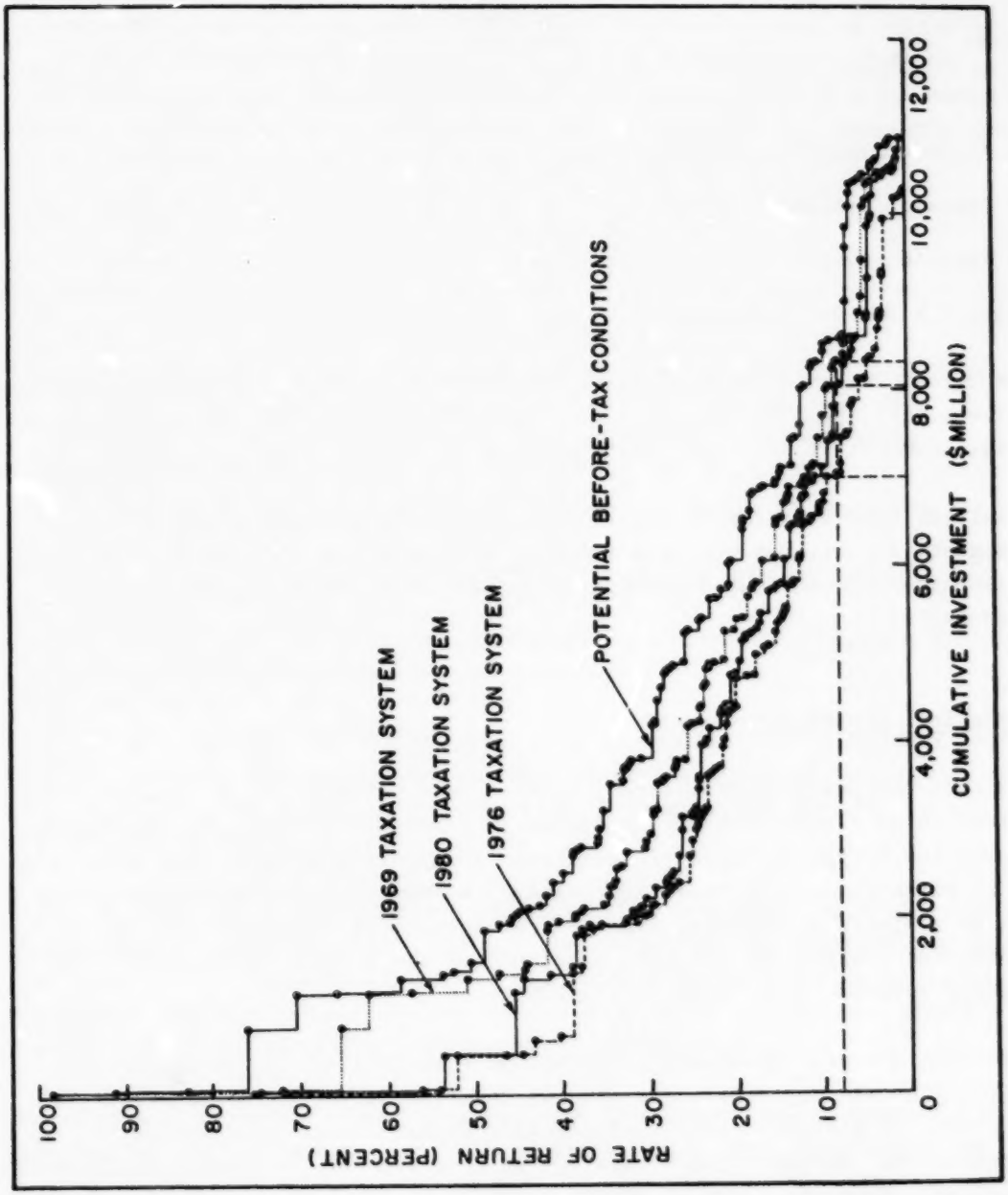


Figure 7. Effect of Actual Mining Taxation Systems on Investment Demand

TABLE 5
ACTUAL MINING TAXATION SYSTEM VARIANTS
(8-percent discount rate)

Variant	Number of Deposits Justifying Development	Cumulative Investment Demand ($ Million)
Base case[a]	87	8 560
1969 taxation system	84	8 310
1976 taxation system	74	7 000
1980 taxation system	81	8 030

[a]Before-tax potential values.

These actual taxation regimes reduce the number of economic deposits by between 3 percent (for the 1969 system) and 15 percent (for the 1976 system). Consequently, cumulative investment demand falls by between 3 and 18 percent.

A practical understanding of the relationship between taxation and mineral investment, illustrated by these results, is fundamental to policy analysis. The investment demand curve provides a useful mechanism for assessing this relationship.

Hypothetical Taxation Systems

The actual changes in mining taxation which have occurred in Canada represent a combination of alterations in the system or structure of taxation and variations in the burden or level of taxation. In order to separate the effects of each of these factors on investment demand, we now look at the results which would be achieved by applying hypothetical systems of taxation based on the revenue, the profit, and the rate of return of the mining operation.[13] The following systems are defined for this purpose.

i Revenue system - government taxation at v percent of the annual revenue from economic deposits. The rate of taxation is varied to determine the effects of different levels of taxation within the revenue system.

ii Profit system - government taxation at t percent of the annual profit from economic deposits. Annual profit is defined as annual revenue less annual operating cost and depreciation allowance. Depreciation is allowable at

13. The application of these hypothetical tax systems does not consider the expensing of exploration expenditures, and taxes development and production phases on an individual project basis.

20 percent per year on a declining-balance basis. The rate of taxation is varied to determine the effects of different levels of taxation within the profit system.

iii Rate of return system - the government taxation rate is a function of the rate of return on investment. This type of system gives tax relief below a certain threshold rate of return (usually representing the discount rate), with the tax rate increasing above that threshold value to a maximum marginal rate for projects with a high rate of return. The rate-of-return system applied in this study is of the following form:

$$y = a - \frac{ba}{x}$$

where:

y = government taxation rate expressed as a percentage of annual operating profit (annual revenue less annual production cost), y 0;

b = the discount rate (threshold rate) expressed as a percentage;

x = before-tax discounted cash flow rate of return for the development and production phases of mineral investment as revealed up to and including present year;

a = a constant representing the maximum marginal taxation rate.

The value of 'a' is varied to determine the effects of different levels of taxation within the rate of return system.

First of all, we consider what happens when various levels of taxation within each of the hypothetical systems are imposed on the potential investment demand conditions shown in figure 4. A wide range of tax levels has been chosen for illustrative purposes.

Figure 8 shows the effect of the hypothetical revenue taxation system for v = 10 percent, 25 percent and 40 percent. Imposition of the hypothetical profit system for t = 20 percent, 50 percent and 80 percent is illustrated in figure 9. Figure 10 shows the effect of the hypothetical rate-of-return system for b = 8, and a = 40 percent, 60 percent, and 90 percent.

In all cases, as taxation is increased, the investment demand schedules shift down and to the left relative to the potential value conditions. For the hypothetical revenue taxation system (figure 8), the slope of the schedule does not appear to be affected and the curves are displaced in a roughly parallel fashion. This indicates that a revenue tax of this type imposes a uniform burden indiscriminately across marginal and more profitable projects alike.

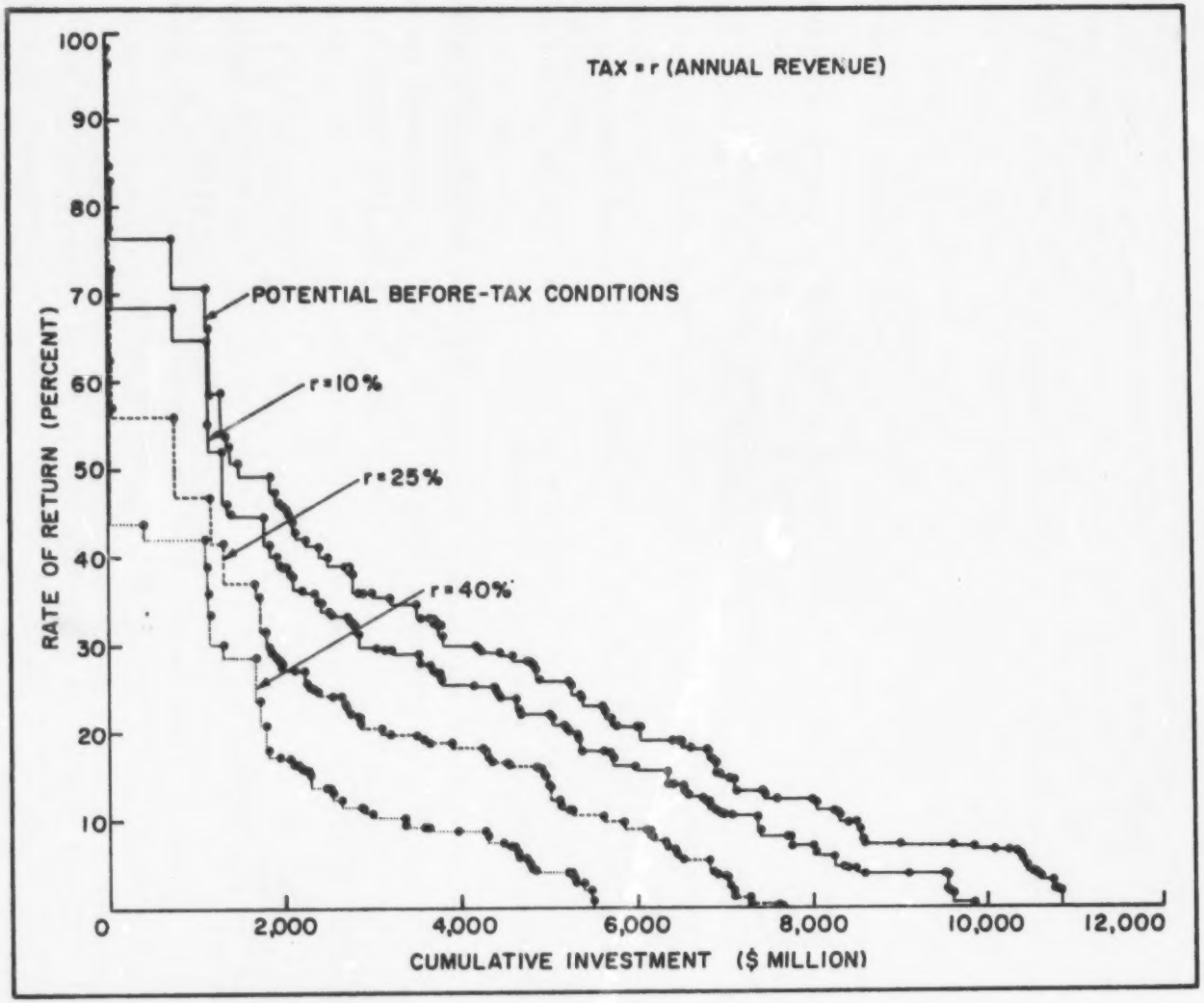


Figure 8. Effect of Hypothetical Revenue Taxation System on Investment Demand

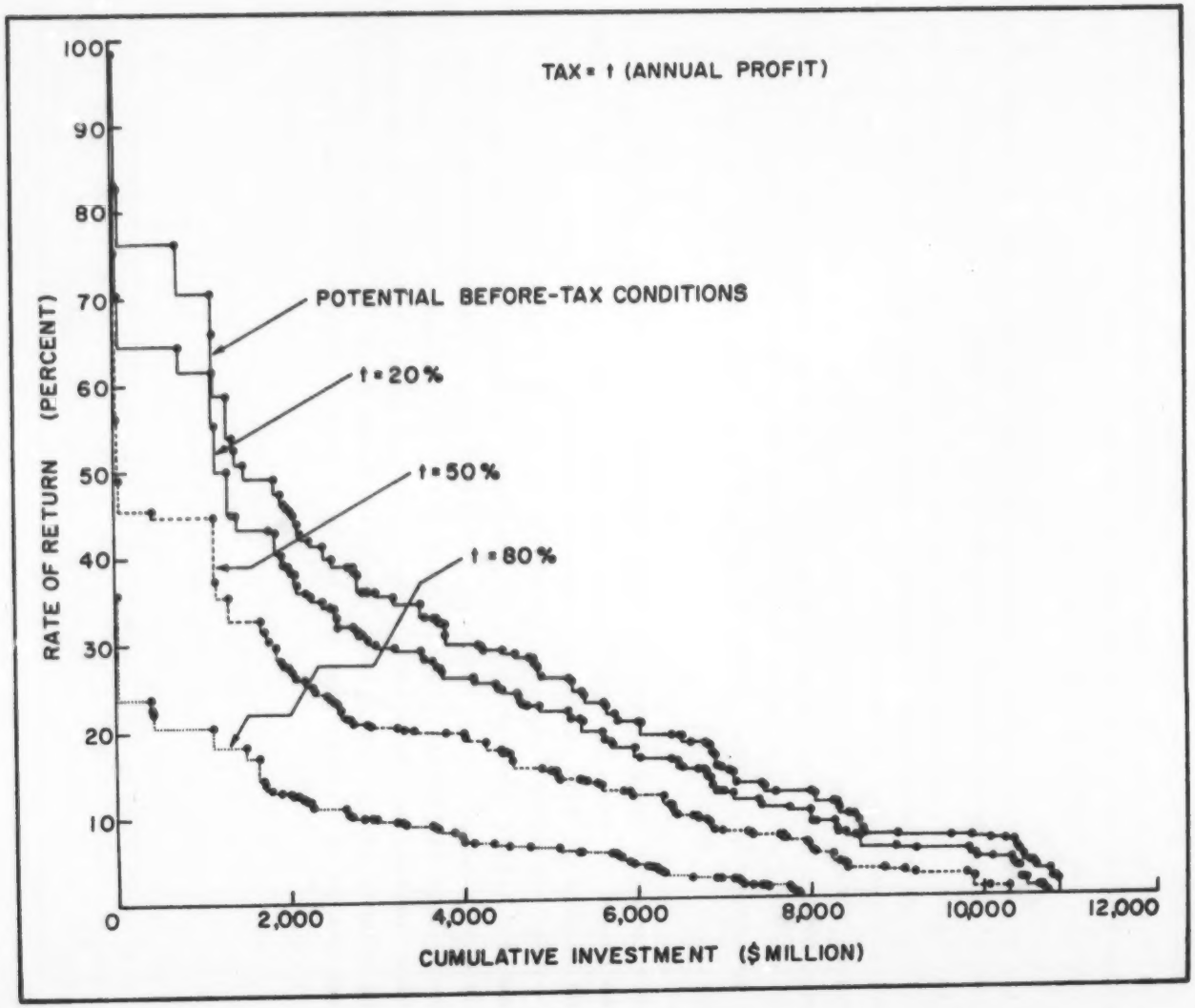


Figure 9. Effect of Hypothetical Profit Taxation System on Investment Demand

After-tax demand curves for the hypothetical profit tax system are flatter for higher rates, pivoting around a point which lies towards the lower right of figure 9. Thus, to the extent that the profitability of projects is a function of 'annual profit', the profit system affords some relief to marginal projects and taxes more profitable projects more heavily. Thus, the effect of the system on reducing the number of deposits justifying development and cumulative investment would not be as pronounced as for the revenue system, provided that the overall tax burden is the same.

For the hypothetical rate-of-return system, the investment demand curves pivot around 'b', the threshold rate, assumed to be 8 percent in the results presented in figure 10. Below this point no tax is levied, and thus the before-tax and after-tax schedules are identical. Above the threshold rate, the rate of taxation increases as a function of profitability, shown by the increasing displacement between the curves. If the threshold rate selected represents the minimum return that the company requires on mining projects, such a tax system would not reduce the number of projects justifying development or the cumulative investment demanded. These would remain at their potential before-tax values.

Table 6 compares results for the three hypothetical taxation systems in terms of the number of deposits justifying development and the cumulative investment demand associated with their development, assuming an 8-percent investment margin. These parameters are very sensitive to the rate of taxation for the revenue and profit systems, but are maintained at their before-tax values in the case of rate-of-return taxation, irrespective of the overall tax burden imposed. This illustrates an important policy advantage of rate-of-return taxation compared to the other systems. Of course, to make a valid comparison of the effects of the tax systems themselves, the level or burden of taxation imposed has to be standardized across the systems. This will now be done.

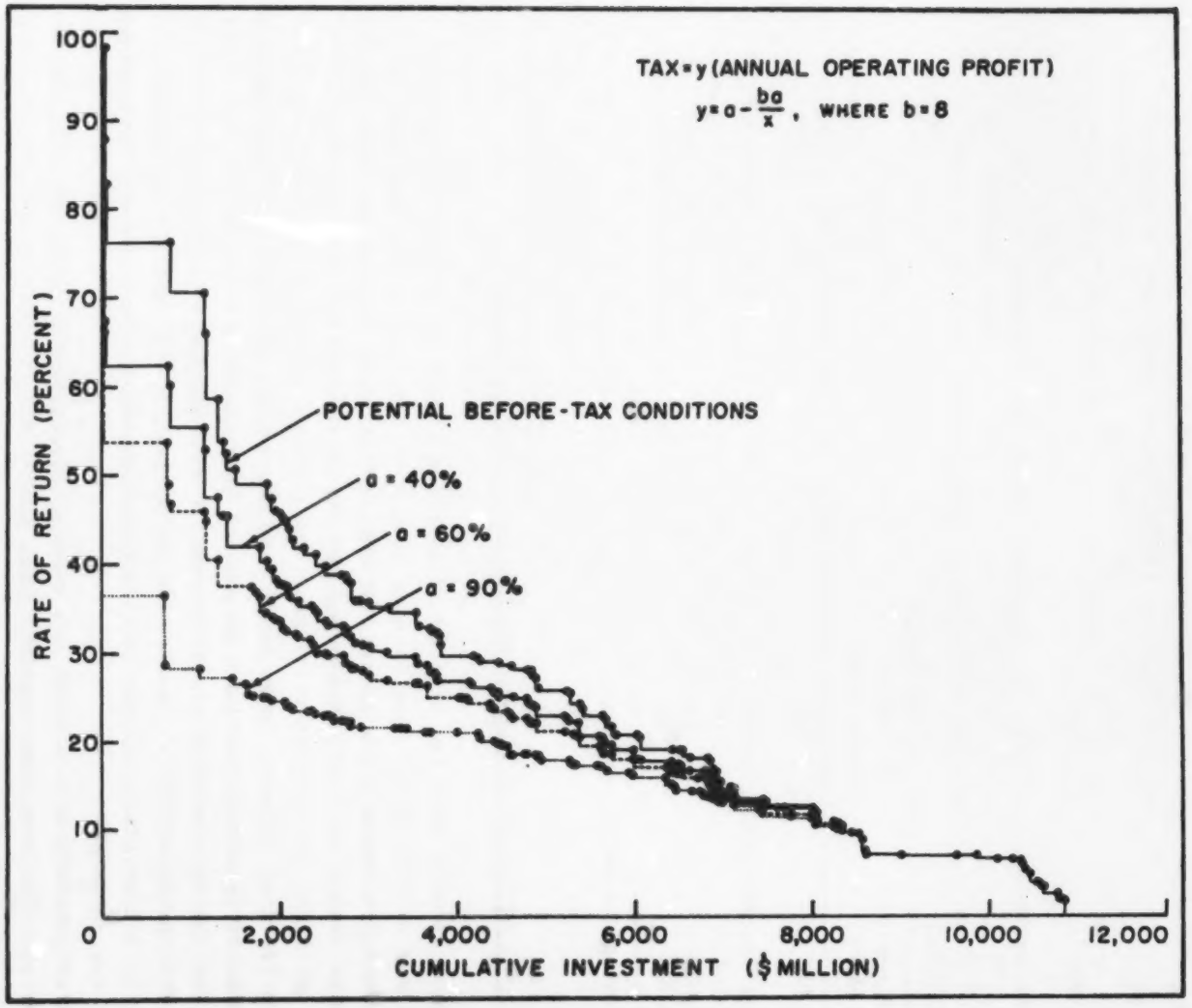


Figure 10. Effect of Hypothetical Rate-of-Return Taxation System on Investment Demand

TABLE 6
HYPOTHETICAL MINING TAXATION SYSTEM VARIANTS
(8-percent discount rate)

Variant	Number of Deposits Justifying Development	Cumulative Investment Demand ($ Million)
Base case[a]	87	8 560
Revenue system:		
v = 10%	78	7 746
v = 25%	58	6 174
v = 40%	33	4 305
Profit system:		
t = 20%	82	8 270
t = 50%	67	6 825
t = 80%	31	3 880
Rate-of-return system (b=8):		
a = 40%	87	8 560
a = 60%	87	8 560
a = 90%	87	8 560

[a]Before-tax potential values

Comparison of Taxation Systems for Constant Levels of Taxation

The above results show the effects of changing levels or burdens of taxation on investment demand, given a particular system of taxation. The next step in our analysis is to compare the effects of various taxation systems for constant levels of taxation.[14] The following two levels are used:

i The level of taxation associated with the actual 1980 system. The required rates of taxation have been determined as follows:
- for the hypothetical profit system, t = 52 percent;
- for the hypothetical rate-of-return system, b = 8, and a = 64 percent.
It is not possible for the hypothetical revenue system to yield this amount of tax revenue.

ii Three-quarters of the total tax revenue associated with the actual 1980 system. The required taxation rates are:
- for the hypothetical revenue system, v = 25.7 percent;
- for the hypothetical profit system, t = 35 percent;
- for the hypothetical rate-of-return system, b = 8 and a = 48.

14. For this purpose, the level of taxation is defined as the present value of total tax payments discounted at 3 percent.

Empirical investment demand schedules have been constructed for each of these levels of taxation. However, there was insufficient separation among the curves to give meaningful results. We have taken this graphical method of analysis about as far as it can go. Summary results for the two levels of total tax revenue considered are presented in table 7.

TABLE 7
TAXATION SYSTEMS: CONSTANT LEVELS OF TAXATION
(8-percent discount rate)

Variant	Number of Deposits Justifying Development	Cumulative Investment Demand ($ Million)
Base case[a]	87	8 560
1980 system tax level:		
Actual system	81	8 030
Profit system (t = 52%)	67	6 825
Rate-of-return system (b=8, a=64%)	87	8 560
Three-quarters of 1980 system tax level:		
Revenue system (v = 25.7%)	56	6 133
Profit system (t = 35%)	79	7 990
Rate-of-return system (b=8, a=48%)	87	8 560

[a]Before-tax potential values

For the level of taxation associated with the actual 1980 Canadian system, rate-of-return taxation gives more attractive results than the actual system in terms of number of economic deposits and cumulative investment, while the profit system gives less desirable results. It is of interest to note that results for the actual system are much closer to the rate-of-return system results than to those of the pure profit tax system considered. Thus, the jungle of taxation allowances and rates currently in place at federal and provincial levels combine, it seems, to work as a function of rate of return.

Results for the lower tax level, with total tax revenue standardized at three-quarters of that yielded by the actual 1980 systems, once again clearly show the advantages of rate-of-return taxation and, even more dramatically, the desirability of a profit system of taxation compared to a tax on revenue. The relative effects of these taxation systems are further examined in chapter 5 in terms of the interest elasticity of investment demand.

Investment demand curves derived from relevant empirical data provide the basis for evaluating the effects of public policy, such as mining taxation, on investment. The graphical presentation and comparison of schedules, as shown in this section, are useful for the analysis of policy effects. We now look at applying the concept of the interest elasticity of investment demand to the schedules presented, showing how it can simplify the definition of the curves as well as enabling further and more detailed insights into changes in their shapes and slopes.

5. EVALUATING THE INTEREST ELASTICITY OF INVESTMENT DEMAND

In this section, we attempt to evaluate empirically the interest elasticity of mineral investment demand. These results will permit more detailed comment on the characteristics of the investment demand schedules and on the implications of variations in mining taxation for investment behaviour.

Elasticity, as previously outlined, is interpreted with reference to movement along the investment demand curve. The elasticity of investment demand is the degree of responsiveness of investment to a change in the rate of return. Again, elasticity is the percentage change in investment demanded in response to a one percent (not percentage point) change in the rate of return.[15]

We first look at the assumption made in the 1978 study by the Ontario Ministry of Natural Resources that the elasticity of investment demand is unitary. Unitary elasticity means that there would be a constant one-to-one relationship between percentage changes in rate of return and investment demand throughout the schedule. Figure 11 compares the empirical investment demand schedule for base case conditions with a theoretical curve having unitary elasticity which passes through the 8-percent rate of return - investment demand coordinates on the empirical curve. It is obvious by inspection that the elasticity of the empirical schedule is much less than one, a condition we found throughout the study. Thus, empirically, investment demand appears to be less responsive to

---

15. Mathematically, interest elasticity of investment demand can be defined in the following manner. Let: I = investment; r = rate of return. Now, in general form:

$$I = \Phi(r); \quad \Phi'(r) < 0.$$

The investment demand curve is negatively sloped. Slope can also be expressed as dI/dr. At a point on the demand curve, elasticity is defined as:

$$n = \frac{dI}{I} \Big/ \frac{dr}{r}.$$

This is called 'point elasticity of demand'. For a discrete change in the rate of return, elasticity is estimated by the following formula:

$$n = \frac{\Delta I}{(I_1 + I_2)/2} \Big/ \frac{\Delta r}{(r_1 + r_2)/2}.$$

This evaluates elasticity at the mid-point in the interval over which the change occurs, and assumes that the demand curve is linear over this range.

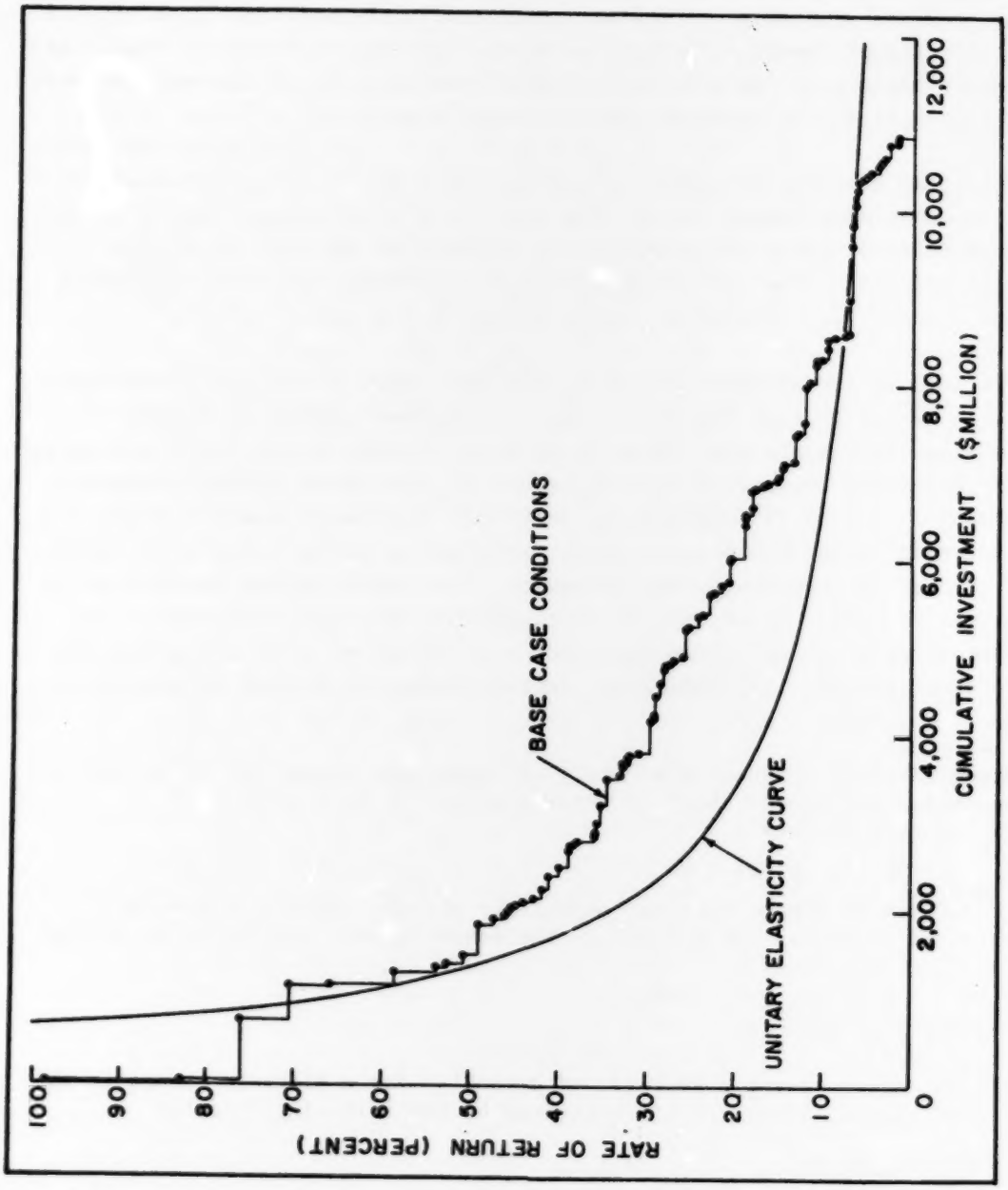


Figure 11. Empirical Investment Demand Curve for Base Case Conditions in Relation to Unitary Elasticity Investment Demand Curve

changes in rate of return than would be indicated by the unitary elasticity assumption.

We next tested the empirical demand schedules for constant elasticity. Constant elasticity would mean that the relationship between the one-percent change in rate of return and the corresponding change in investment demand is constant along the entire range of the curve.[16] For this purpose, we transformed our investment demand curves to logarithmic form and fitted straight lines to the transformed data.[17] The fit of these straight lines to our transformed data was generally poor. Thus, the empirical data do not support the assumption of constant elasticity of investment demand.

Finally, we noted that the investment demand schedules themselves appear to be linear except at very high rates of return (generally above 50 percent). Straight-line fits over relevant rate-of-return ranges gave very good correlation coefficients. Elasticity estimates could then be derived from such results for particular rate-of-return intervals. We have found that this assumption of a linear investment demand curve gives suitable results for meaningful analysis of the characteristics of investment demand and their response to public policy. Thus, the elasticity estimates analyzed are derived from linear relationships between investment and rate of return, in their natural values.

In general, a linear investment demand schedule implies low elasticities at low rates of return and higher elasticities at higher rates of return. This is characteristic of our empirical data and explains why it does not satisfy the conditions required for unitary or, more generally, for constant elasticity.

While we are interested in how elasticities change along the entire demand schedule, it is the elasticity around the investment margin which is of critical importance, because this is the elasticity which governs the real-world effect of a change in rate of return resulting from a change in public policy. For this reason, in the analysis which follows, we will be paying particular attention to the interest elasticity of investment demand in the rate-of-return intervals 5-15 percent and 0-10 percent.

Table 8 presents detailed elasticity estimates for the potential before-tax investment demand schedule shown in figures 4 and 11, given base case conditions (i.e. all base metal deposits discovered in Canada during the period

16. This constant relationship would obviously be less than one-to-one in our case.
17. Thus, the estimated constant elasticity is the inverse of the slope of each straight line.

TABLE 8
DETAILED ELASTICITY ESTIMATES: BASE CASE CONDITIONS

Rate of Return (Percent)		Elasticity Estimate	Correlation Coefficient	Sample Size
Range	Interval			
0-20		-0.323	-0.974	45
	0-10	-0.139		
	5-15	-0.323		
0-30		-0.481	-0.984	66
	0-10	-0.121		
	5-15	-0.277		
	10-25	-0.611		
	15-25	-0.764		
0-40		-0.697	-0.989	85
	0-10	-0.114		
	5-15	-0.258		
	10-25	-0.561		
	15-25	-0.697		
0-50		-0.945	-0.985	96
	0-10	-0.108		
	5-15	-0.241		
	10-25	-0.515		
	15-25	-0.636		
	25-50	-2.685		
0-125		-8.687	-0.894	106
	0-10	-0.078		
	5-15	-0.169		
	10-25	-0.339		
	15-25	-0.407		
	25-50	-1.187		
0-10		-0.160	-0.889	22
5-15		-0.414	-0.944	24
10-25		-0.551	-0.981	31
15-25		-0.677	-0.970	20
25-50		-1.900	-0.976	43
50-125		-3.716	-0.905	10

1951-74 evaluated with expected metal prices). Straight line fits were made for each of the rate-of-return ranges specified. The elasticity estimate for the midpoint, correlation coefficient, and sample size (number of deposits) are given for each range. Elasticity estimates are then derived for rate-of-return intervals within each range.

The high correlation coefficients and large sample sizes indicate that the assumption of a linear investment demand schedule is valid except at the high rate-of-return end of the curve. Furthermore, the elasticity estimates for rate-of-return intervals are reasonably consistent across the various ranges. Similar statistical results for other variants confirmed the reliability of the linear assumption.

In the presentation of results which follow, results for the 0-50 percent rate-of-return range have been selected as representative and the following intervals have been used:

i 0-10 percent;
ii 10-25 percent;
iii 5-15 percent;
iv 15-25 percent;
v 25-50 percent;

In each case, the elasticity estimate at the range midpoint, the correlation coefficient obtained, and the sample size for the overall range (0-50 percent) are given in a statistical note.

Table 9 shows the summary elasticity results for the potential before-tax base case conditions. While the elasticity estimate for the midpoint at the 0-50 percent rate-of-return range is in fact close to one (0.945), elasticities around the investment margin, the relevant concern for policy analysis purposes, are only in the order of -0.1 to -0.3.

Elasticity results for mining projects within the shield and cordilleran regions, derived from the investment demand schedules illustrated in figure 5, are compared in table 10. The striking difference in investment characteristics between these two mineral endowment variants that was noted previously is confirmed here. Investment demand in the shield region is extremely inelastic, about -0.5 for the 0-50 percent range and -0.05 to -0.15 around the investment margin. While investment demand is more elastic in the cordilleran region, -1.24 over the range, elasticity is still only in the order of -0.1 to -0.3 at the margin of investment. Generally, the interest elasticity of investment demand will be a function of deposit type and geological environment, a factor which warrants attention in mineral policy analysis.

TABLE 9
SUMMARY ELASTICITY ESTIMATES: BASE CASE CONDITIONS

Rate-of-Return Interval (Percent)	Elasticity Estimate
0-10	-0.108
10-25	-0.515
5-15	-0.241
15-25	-0.636
25-50	-2.685

Statistical Notes
Rate-of-return range = 0-50%

Elasticity estimate:	-0.945
Correlation coefficient:	-0.985
Sample size:	96

TABLE 10
ELASTICITY ESTIMATES: MINERAL ENDOWMENT VARIANTS

Rate-of-Return Interval (Percent)	Elasticity Estimates		
	Canada	Shield	Cordilleran
0-10	-0.108	-0.071	-0.124
10-25	-0.515	-0.301	-0.632
5-15	-0.241	-0.152	-0.284
15-25	-0.636	-0.359	-0.795
25-50	-2.685	-0.982	-4.890

Statistical Notes
Rate-of-return range = 0-50%

	Canada	Shield	Cordilleran
Elasticity estimate:	-0.945	-0.493	-1.240
Correlation coefficient:	-0.985	-0.983	-0.946
Sample size:	96	40	34

Table 11 presents elasticity estimates for each of the metal price variants. Results show that the investment demand schedule steepens somewhat as metal prices are increased. Although it was not apparent in figure 6, the curves are twisted somewhat from a pivot which lies below and to the right of the figure. The slopes of the curves change in this way because changes in price generally have a greater absolute effect on the rate of return for more highly profitable projects than for more marginal projects. Thus, the vertical displacement between the curves increases as we proceed up them.[18] Consequently, the interest elasticity of investment demand is an inverse function of metal price.

TABLE 11
ELASTICITY ESTIMATES: PRICE VARIANTS

Rate-of-Return Interval (Percent)	Elasticity Estimates		
	Lower Limit	Expected Prices	Upper Limit
0-10	-0.125	-0.108	-0.079
10-25	-0.636	-0.515	-0.343
5-15	-0.286	-0.241	-0.171
15-25	-0.799	-0.636	-0.412
25-50	-4.988	-2.685	-1.206

Statistical Notes
rate-of-return range: 0-50%

	Lower Limit	Expected Prices	Upper Limit
Elasticity estimate:	-1.249	-0.945	-0.574
Correlation coefficient:	-0.959	-0.985	-0.990
Sample size:	59	96	83

18. We also considered the extent to which this 'twisting' was caused by variations in relative price ratios among the three sets of metal prices. For this purpose, investment demand schedules were also generated and elasticities estimated for sets of constant relative prices based on the expected value conditions and the copper price limits. Results indicated that the twisting was even more pronounced for the constant relative price conditions, particularly at lower limit prices.

We now consider the effects of taxation on the elasticity of investment demand by applying the actual and hypothetical tax systems introduced in chapter 4 to the potential before-tax investment demand curve shown in figures 4 and 11.

First of all, elasticity estimates for investment demand curves after imposition of the actual 1969, 1976 and 1980 Canadian taxation systems are compared with before-tax conditions in table 12. Taxation increases the interest elasticity of investment demand, but elasticities around the investment margin, in the order of -0.15 to -0.35, are still much less than unity. The greater the burden of taxation, the higher the elasticity of investment demand (i.e. 1976 system elasticities > 1980 system elasticities > 1969 system elasticities). Results for the 1980 system are much closer to the 1976 system elasticities than those associated with the 1969 tax system.

Next, we turn our attention to the effects of changing levels of taxation within each of the hypothetical tax sytems. Table 13 presents elasticity estimates for the hypothetical revenue tax system. Although the investment demand schedules, shown in figure 8, appeared to shift in a parallel fashion, we can now see that there is in fact a modest but systematic reduction in slope (increase in elasticity) as the level of revenue tax is applied and increased. This indicates that, for the 131 deposits included in our study, there is a modest direct relationship between revenue and profitability. Thus, a higher rate of revenue tax places a somewhat higher burden on more profitable projects than it does on less profitable projects.

Elasticity estimates for the hypothetical profit system are given in table 14. As the rate of profit tax is increased, there is a significant increase in elasticity, consistent with the flattening of the investment demand schedules observed in figure 9. This reflects the direct relationship which exists between profit and profitability.

Table 15 shows elasticity estimates for the hypothetical rate-of-return system. As the burden of taxation is increased, elasticities once again increase, modestly at lower profitabilities and more substantially for higher profitabilities.[19] This reflects the direct relationship between the tax rate and profitability embodied in this type of taxation system. These results confirm the observations made on the investment demand schedules presented in figure 10.

Finally, we compare the effects of the various systems of taxation for two particular levels of taxation. Elasticity estimates for the hypothetical profit

19. Elasticities will only change above the threshold rate, 'b', 8 percent in this case.

TABLE 12
ELASTICITY ESTIMATES: ACTUAL TAXATION SYSTEMS

Rate-of-Return Interval (Percent)	Elasticity Estimates			
	Before Tax	1969 Taxation System	1976 Taxation System	1980 Taxation System
0-10	-0.108	-0.124	-0.144	-0.140
10-25	-0.515	-0.632	-0.787	-0.750
5-15	-0.241	-0.284	-0.336	-0.324
15.25	-0.636	-0.795	-1.013	-0.960
25-50	-2.685	-4.890	-16.969	-11.251

Statistical Notes
Rate-of-return range = 0-50%

	Before Tax	1969 System	1976 System	1980 System
Elasticity estimate	-0.945	-1.240	-1.695	-1.579
Correlation coefficient	-0.981	-0.981	-0.976	-0.970
Sample size	96	99	96	102

TABLE 13
ELASTICITY ESTIMATES: HYPOTHETICAL REVENUE TAXATION SYSTEM
Tax = v (Annual Revenue)

Rate-of-Return Interval (Percent)	Elasticity Estimates			
	Before Tax	v = 20%	v = 25%	v = 40%
0-10	-0.108	-0.131	-0.138	-0.142
10-25	-0.515	-0.680	-0.739	-0.774
5-15	-0.241	-0.301	-0.321	-0.322
15.25	-0.636	-0.861	-0.944	-0.994
25-50	-2.685	-6.533	-10.180	-14.312

Statistical Notes
Rate-of-return range = 0-50%

	Before Tax	v = 20%	v = 25%	v = 40%
Elasticity estimate	-0.945	-1.371	-1.545	-1.653
Correlation coefficient	-0.985	-0.984	-0.968	-0.897
Sample size	96	73	70	50

TABLE 14
ELASTICITY ESTIMATES: HYPOTHETICAL PROFIT TAXATION SYSTEM
Tax = t (Annual Profit)

Rate-of-Return Interval (Percent)	Elasticity Estimates			
	Before Tax	t = 20%	t = 50%	t = 80%
0-10	-0.108	-0.123	-0.155	-0.294
10-25	-0.515	-0.619	-0.882	-3.881
5-15	-0.241	-0.279	-0.366	-0.833
15-25	-0.636	-0.776	-1.153	-9.955
25-50	-2.685	-4.528	-	-
Statistical Notes:				
Rate-of-return range = 0-50%				
	Before Tax	t = 20%	t = 50%	t = 80%
Elasticity estimate	-0.945	-1.203	-2.026	-
Correlation coefficient	-0.985	-0.981	-0.952	-0.919
Sample size	96	98	92	71

TABLE 15
ELASTICITY ESTIMATES: HYPOTHETICAL RATE-OF-RETURN TAXATION SYSTEM (b=8)
Tax = y (Annual Operating Profit); $y = a - \frac{ba}{x}$, where b = 8

Rate-of-Return Interval (Percent)	Elasticity Estimates			
	Before Tax	a = 40%	a = 60%	a = 90%
0-10	-0.108	-0.126	-0.135	-0.197
10-25	-0.515	-0.643	-0.715	-1.353
5-15	-0.241	-0.288	-0.313	-0.489
15-25	-0.636	-0.809	-0.910	-1.916
25-50	-2.685	-5.182	-8.366	-
Statistical Notes				
Rate-of-return range = 0-50%				
	Before Tax	a = 40%	a = 60%	a = 90%
Elasticity estimate	-0.945	-1.267	-1.472	-4.598
Correlation coefficient	-0.985	-0.987	-0.978	-0.988
Sample size	96	100	104	106

and rate-of-return systems and for the actual 1980 system are compared in table 16, based on the total tax revenue associated with the actual 1980 taxation system.[20] As can be seen from the results, the actual 1980 system, nominally a 'profit' system, has elasticity characteristics similar to the hypothetical rate-of-return system, and significantly lower than those of the hypothetical profit system.

Table 17 presents elasticity estimates for the hypothetical revenue, profit, and rate-of-return systems of taxation, at a level of taxation equal to three-quarters of the total tax revenue yielded by the actual 1980 taxation system. Here we see that the hypothetical profit system produces an investment demand schedule with elasticities that are very similar to those resulting from the hypothetical revenue system, and higher than those associated with the hypothetical rate-of-return system.

These results further illustrate the advantage of a system of taxation which is based on the rate of return of mining projects in minimizing policy inefficiencies at the investment margin.

This chapter has shown how elasticity estimates based on empirical data can assist in understanding the characteristics of mineral investment demand and the direct effects of public policies, such as mining taxation, thereon.

20. The hypothetical revenue system cannot yield this level of taxation.

TABLE 16
ELASTICITY ESTIMATES: 1980 SYSTEM TAX LEVEL

Rate-of-Return Interval (Percent)	Elasticity Estimates: Actual 1980 System	Profit System t = 52%	Rate-of-Return System b = 8, a = 64%
0-10	-0.140	-0.161	-0.141
10-25	-0.750	-0.940	-0.764
5-15	-0.324	-0.383	-0.329
15-25	-0.960	-1.241	-0.980
25-50	-11.251	-	-12.885

Statistical Notes
Rate-of-return range = 0-50%

	Actual 1980 System	Profit System t = 52%	Rate-of-Return System b = 8, a = 64%
Elasticity estimate	-1.579	-2.247	-1.622
Correlation coefficient	-0.970	-0.952	-0.981
Sample size	102	92	104

TABLE 17
ELASTICITY ESTIMATES: THREE-QUARTERS OF 1980 SYSTEM TAX LEVEL

Rate-of-Return Interval (Percent)	Elasticity Estimates: Revenue System v = 25.7%	Profit System t = 35%	Rate-of-Return System b = 8, a = 48%
0-10	-0.140	-0.140	-0.130
10-25	-0.751	-0.757	-0.674
5-15	-0.325	-0.326	-0.299
15-25	-0.961	-0.969	-0.852
25-50	-11.318	-11.973	-6.271

Statistical Notes
Rate-of-return range = 0-50%

	Revenue System v = 25.7%	Profit System t = 35%	Rate-of-Return System b = 8, a = 48%
Elasticity estimate	-1.581	-1.600	-1.353
Correlation coefficient	-0.964	-0.975	-0.984
Sample size	67	94	101

6. CONCLUSIONS

The 1978 study by the Ontario Ministry of Natural Resources (MNR) to evaluate the effects of policy on mineral investment behavior was based on the critical assumption that the interest elasticity of investment demand is unitary. The significance of this assumption is that measured policy changes can be directly translated into measurable effects in mineral investment. This working paper has undertaken an empirical examination of this assumption.

Our analysis, based on actual data for 131 Canadian base metal deposits, indicates that the assumption is invalid. Our findings show that mineral investment demand is interest inelastic, especially over that critical range of rates of return within which real-world mineral investment decisions are made. Within this critical range of 5 to 15 percent rate of return, estimated elasticity coefficients are generally less than -0.4. Since we find interest elasticity to be substantially lower than the MNR assumption of unity, the depressing impact of taxes on mineral investment can also be expected to be considerably less than that predicted in the MNR study.

Furthermore, our empirical data do not support the assumption of constant elasticity of investment demand. Rather, the investment demand schedules are found to be essentially linear except at very high rates of return (generally above 50 percent). This means that elasticity changes with movement along the investment demand curve; low elasticities are associated with low rates of return and higher elasticities with higher rates of return. This explains why our empirical data do not satisfy the conditions required for unitary or, more generally, for constant elasticity.

Empirical measures of responsiveness of investment behaviour to changes in the rate of return are sensitive to differences in mineral endowment characteristics and to variations in metal prices. For example, there is a striking difference in investment characteristics between mining projects in the shield and cordilleran region. Investment demand in the shield region is extremely inelastic, reflecting the generally high and variable rates of return of mining projects and their relatively low investment requirements. The more marginal and less variable rates of return, and the heavier investment demands of projects in the cordilleran region result in a much flatter investment demand schedule and higher elasticities. The investment demand schedule steepens as metal prices are increased. Consequently, the interest elasticity of investment demand is an inverse function of metal price. These factors warrant attention in mineral policy analysis.

A major concern of this paper is the implications of tax systems for investment behaviour. Specifically, the effect of taxes on interest elasticity of investment demand was examined in some detail. Taxes shift the investment demand curve downward and to the left of the before-tax investment demand curve. The amount of displacement varies directly with the level or rate of taxation. The type of displacement which occurs depends on the system of taxation applied. In general, taxation increases the interest elasticity of investment demand.

Particularly noteworthy is the impact of taxation over the critical 5 to 15 percent rate-of-return interval. This determines the actual effect of taxation on investment demand. The impact depends on four key variables:

i mineral endowment characteristics;
ii metal prices;
iii the level of taxes;
iv the system of taxation.

Mineral endowment characteristics and metal prices fix the shape of the before-tax investment demand curve. The level and the system of taxation imposed then define the displacement which occurs around the investment margin. In general, a rate-of-return system of taxation is shown to have less impact on reducing potential before-tax investment demand than other actual and hypothetical tax systems examined.

A practical understanding of the relationship between taxation and mineral investment is fundamental to policy analysis. Investment demand curves and elasticity estimates, based on relevant empirical data, are useful mechanisms for assessing this relationship.

THE AUTHORS

Brian W. Mackenzie, a native of Winnipeg, was born in 1939. He holds a B.Eng. (Hon.) in mining from McGill University, an M.Sc. in mineral economics from Witwatersrand, and a doctorate in engineering science (mineral economics) from Columbia University. After working as an engineer in mines in Canada and South Africa, he became an assistant inspector of mining leases for the South African government, and later worked as a mineral economist with Energy, Mines and Resources in Ottawa. Dr. Mackenzie then taught in the Department of Mining and Metallurgical Engineering at McGill University, where he was director of the mining program, until 1977. In January 1978 he became a research associate of the Centre for Resource Studies and a professor in the Department of Geological Sciences at Queen's University.

Charles Pye was born in Halifax. He holds B.A. and B.Com. degrees from Dalhousie University and an M.A. degree in Economics from Queen's University. After graduating from Queen's he joined the faculty of Memorial University of Newfoundland, where he held a teaching position in the Department of Economics. In 1976 he came to the Centre for Resource Studies as a research associate, and in 1980 Mr. Pye accepted the position of economist with the Department of Development of the Government of Nova Scotia.

THE CENTRE FOR RESOURCE STUDIES

The Centre for Resource Studies (CRS) was established in 1973, under the sponsorship of Queen's University, the federal Department of Energy, Mines and Resources, and The Mining Association of Canada, to carry out a program of research and publication on mineral policy issues.

The Centre provides opportunities for multidisciplinary research in resource studies at Canadian universities, furnishes reliable information on matters related to mineral resource policy, and promotes closer liaison between government, industry and other concerned groups. The research program is carried out both at the Centre and by means of contracts with qualified investigators, usually at Canadian universities. Small exploratory studies are funded through a system of grants-in-aid of research. CRS Seminars involve representatives from governments, industry, universities, labour, and other interested groups in working sessions on issues of current concern. Through this program of research and seminars, and the resulting publications, the Centre contributes to informed discussions and a better understanding of significant issues.

The Centre is governed by a board of directors which establishes general policy and priorities for research. The board has sixteen members, appointed by Queen's University, The Mining Association of Canada, and the federal government. Guidance on the research program, together with discussion of policy issues and other matters, is provided by the Advisory Council. This body comprises all researchers associated with the Centre, together with members appointed from such groups as governments, industry, labour, and consumers. A Research Advisory Committee aids in the development of projects and the selection of research proposals. The executive director and staff are responsible for the work of the Centre within this framework.

Most of the funding for the Centre's activities is provided by the sponsors. In addition, the Centre accepts contracts from other organizations interested in mineral policy research.

The Centre welcomes comments on its publications, proposals for research projects or for publication, or enquiries about any aspect of its work. For further information, contact:

Centre for Resource Studies
Queen's University
Kingston, Ontario, Canada K7L 3N6
(613) 547-5957

CRS PUBLICATIONS

CRS Publications can be ordered from:
Centre for Resource Studies, 100 Barrie Street, Queen's University, Kingston, Ontario K7L 3N6 (telephone: 613-547-5977)

Monographs (Paperback)

Conflict and its Resolution in the Administration of Mineral Resources in Canada, by R.M. Burns; 62 pages, 11 tables. Published 1976.

The Impact of the Mining Industries on the Canadian Economy, by R.W. Boadway and J.M. Treddenick; 116 pages, 15 tables. Published 1977.

The Transportation Impact of the Canadian Mining Industry, by A.I. Wallace; 154 pages, 17 tables. Published 1977.

Human Resources in Canadian Mining: A Preliminary Analysis, by J.A. MacMillan, G.S. Gislason, and S. Lyon; 174 pages, 48 tables. Published 1977.

Health and Safety in the Canadian Mining Industry, by G.W. Gibbs and P. Pintus; 248 pages, 58 tables. Published 1978.

The Canadian Nonferrous Metals Industry: An Industrial Organization Study, by E. Urquhart; 158 pages, 18 tables. Published 1978.

Economic Impacts and Linkages of the Canadian Mining Industry, by P.E. Nickel, et al; 140 pages, 31 tables. Published 1978.

Environmental Impact of Mining in Canada, by E.A. Ripley, et al, 274 pages, 45 tables. Published 1978.

Effects of Taxation on Base Metal Mining in Canada, by B.W. Mackenzie and M.L. Bilodeau; 188 pages, 29 tables. Published 1979.

Gold: The World Industry and Canadian Corporate Strategy, by E. Cousineau and P.R. Richardson, 192 pages, 32 tables. Published 1980.

The Impact of Policy Change on Decisions in the Mineral Industry: The Case of Exploration in Manitoba, 1969-77, by B.E. Owen and W.J. Kops; 116 pages, 8 tables. Published 1980.

The Role of Mineral Taxation in Industry/Government Conflict: The Case of the Saskatchewan Potash Reserve Tax, by David L. Anderson; 135 pages, 41 tables, 2 illustrations. Published 1981.

Profitability in the Canadian Mineral Industry, by Charles H. Pye; 178 pages, 42 tables, 12 illustrations. Published 1981.

Proceedings

No. 1 Rate-of-Return Taxation of Minerals, with papers by B.W. Mackenzie and M.L. Bilodeau, P.M.T. White, N.D. Olewiler, J.T. Cawley, and E.P. Gush; 109 pages. Published 1978.

No. 2 International Competition and the Canadian Mineral Industries, with papers by H.C. Armstrong, H.T. Fargey, C.G. Miller, N.D. Olewiler and P.R. Richardson, D. Perlstein, and K.C. Hendrick; 109 pages. Published 1978.

No. 3 Current Concerns in Mineral Policy, with papers by C.R. Archibald, W.J. Barbour, D.B. Brooks, J.S. Dowsett, J.M. Fleming, and G.A. Jewett; 75 pages. Published 1978.

No. 4 Canada's Mineral Trade: Implications for the Balance of Payments and Economic Development, with papers by B.W. Wilkinson, D.J. McCulla, J.G. MacKinnon, A.G. Balogh, and W.G. Chambers and J.S. Reid; 113 pages, Published 1978.

No. 5 Employee Relations Initiatives in Canadian Mining, with papers by W.J. Bennett, F.R. Nogas and J.P. Fulcher, W.F. Clarke, S.B. Jones, T.F. Cawsey and P.R. Richardson, and P. Warrian; 85 pages. Published 1979.

No. 6. Junior Mining in Canada: The Problem of Investment and Securing Fair Returns, with papers by A.J. Freyman, B.A. Kalymon, J.D. Mason, D.W. Scrim, E.H. Neave and P.R. Richardson, and E.G. Thompson; 101 pages. Published 1979.

No. 7 The Future for Junior Mining in Canada, with papers by Hon. J.A.C. Auld, J.L.C. Lyndon, N.B. Keevil Jr., D.G.C. Menzel, H.T. Fargey, A.J. Freyman, Hon. R. Hnatyshyn, J.C. Baillie, D.W. Scrim, J.P. Bunting, E.H. Neave and P.R. Richardson, L.A. English, M. St-B Harrison, R.H. Grasley, and Hon. F. Drea; 125 pages. Published 1979.

No. 8 Mining-Linked Diversification of the Sudbury Basin Economy, with papers by D.C. Frith, J.P. Reny, A.I. Wallace, J.H. Holtby and L.C. Kitchener, 53 pages. Published 1980.

No. 9 The Changing Structure of the Canadian Mineral Industry, with papers by I.A. Stewart, R.F. Mikesell, R. Simeon, R. Keyes and J.M. MacLeod; 105 pages. Published 1980.

No. 10 Northern Mining in the 80s, with papers by Hon. G. Braden, R.J. Cathro, D. MacKinnon, J. Smith, R.W. Stephenson, B.E. Novak, E.N. Doyle, J.R. Witty, J.E. Marshall, A.G. Gordon, J. McCormack, H.B. Hicks, J. Zigarlick, T. Shearcroft, W. Kupsch, J. Stabler, and Hon. J. Erola, 110 pages. Published 1980.

No. 11 Skilled Manpower Shortages in the 1980s: Towards a Cooperative Solution, with papers by R.J. Gray, J.S. Reid, W.H. Digby, J.B. Hopkinson, A. Knoll, O. Tremblay, G. Betcherman, P.E. Womersley, M.J. Alton, V.C. Allman, C. Stairs, E.J. Weiss, and W.E. McBride; 116 pages. Published 1981.

No. 12 Acid Rain Controls and the Economics of the Canadian Nonferrous Mineral Industry, with papers by J. Gerin, W.G. Deeks, P.R. Clarke, J.B. Hyne, H.T. Fargey, B.W. Mackenzie, and E.J. Ward; 90 pages. Published 1982, price $9.00.

Working Papers

No. 3 Provincial Mineral Policies: Newfoundland, 1949-75, by M.J. Prince, 67 pages, 7 tables. Published 1977.

No. 6 Provincial Mineral Policies: Saskatchewan, 1945-75, by R.C. Murray; 64 pages. Published 1978.

No. 8 Federal Mineral Policies: 1945-75, by M.J. Wojciechowski; 85 pages, 21 tables. Published 1979.

No. 9 Trends in Canada's Mineral Trade, by B.W. Wilkinson, 63 pages, 27 tables. Published 1978.

No. 10 Canada as a World Zinc Producer: Prospects to 1980, by N.D. Olewiler, P.R. Richardson, and L. Rumble, 22 pages, 12 tables. Published 1978.

No. 11 A Survey of Resources and a Production Cycle for the Nonferrous Metals, by C. Lafkas and J.G. Paterson, 34 pages, 9 tables. Published 1978.

No. 12 Solar Energy and the Canadian Mining Sector: A Demand Forecast, by J.S. Shewchun and D.B. Curtis; 45 pages, 14 tables. Published 1978.

No. 13 Cerro Colorado: A Case Study of the Role of Canadian Crown Corporations in Foreign Mineral Development, by C.G. Miller, N.D. Olewiler, and P.R. Richardson; 44 pages, 5 tables. Published 1979.

No. 14 The Administration of Mineral Exploration in the Yukon and Northwest Territories, by K.A. Graham, R.G. McEachern and C.G. Miller; 42 pages. Published 1979.

No. 15 Public Policy Aspects of Information Exchange in Canadian Mineral Exploration, by D.O.Downing and B.W. Mackenzie, 52 pages. Published 1979.

No. 16 Canada's Competitive Position in Copper and Zinc Markets, by B.W. Mackenzie; 41 pages, 21 tables. Published 1979.

No. 17 Constitutional Change and the Mineral Industry in Canada, by Wendy MacDonald; 66 pages. Published 1979.

No. 18 An Economic Analysis of the Canadian Taxation of an Integrated Mining Company, by Jean-Thomas Bernard; 112 pages. Published 1980.

No. 19 Looking for the Improbable Needle in a Haystack: The Economics of Base Metal Exploration in Canada, by B.W. Mackenzie, 48 pages. Published 1980.

No. 20 The Market Price of Risk in the Canadian Mining Industry, by H.F. Campbell, 29 pages. Published 1980.

No. 21 Public Affairs and the Minerals Industry: Junior Mining; Northern Development; Loans for Foreign Mines; A Public Relations Strategy, by C.G. Miller; 42 pages. Published 1980.

No. 22 Newfoundland Mining Industry: Present Status and Potential for Expansion, by N.D. Olewiler and C.H. Pye; 208 pages, 83 tables. Published 1980.

No. 23 Effects of Water Pollution Control Costs on Base Metal Mining in Canada, by N.A. Papanicolaou and B.W. Mackenzie; 74 pages. Published 1981.

No. 24 The Costs of Uncertainty: Regulating Health and Safety in the Canadian Uranium Industry, by I. Robinson; 74 pages, 3 illustrations. Published 1982.

No. 25 Economic Guidelines for Small Mineral Deposits/Directives économiques relatives aux petits gisements, by B.W. Mackenzie and M.L. Bilodeau; 66 pages, 12 tables, 14 illustrations. Published 1982.

Technical Papers

No. 1 Financing and Stabilization Policies in a Cyclical Industry: The Case of Inco in the Seventies, by W.T. Cannon; 200 pages, 33 tables, 12 illustrations. Published 1981.

No. 2 Economic Effects of Smelter Controls on the Canadian Nonferrous Mining Industry, by B.W. Mackenzie and M.L. Bilodeau; 162 pages, 44 tables, 16 illustrations. Published 1982.

Eastern Arctic Study

The Inuit Land Claim, Constitutional Development, and Local Government Reform in the Northwest Territories: An Overview, by Katherine A. Graham and Anne B. McAllister, 50 pages, published 1981.

Industrial Development in the Eastern Arctic Study Area: A Preliminary Overview, by C. George Miller, 31 pages, published 1981.

Eastern Arctic Study Bibliography Listings, as of June 1, 1981, by M.P. Sharon Brown, 70 pages, published 1981.

Eastern Arctic Study Case Study Series: The Alaska Native Claims Settlement, by David Baker, 100 pages, published 1982.

Eastern Arctic Study Case Study Series: Mineral Exploration in the Baker Lake Area, by Anne B. McAllister, 58 pages, published 1982.

Eastern Arctic Study Case Study Series: The Development of the Polaris Mine, by Katherine A. Graham, 61 pages, published 1982.

Eastern Arctic Study Case Study Series: The Nanisivik Mine, by Margot J. Wojciechowski, 62 pages, published 1982.

QUEEN'S GRAPHIC DESIGN UNIT 6/77-1066